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OUTLINE

OF THE

COURSE OF INSTRUCTION

IN

PHYSICS

GIVEN IN THE

GRAND RAPIDS HIGH SCHOOL

43588

BY

CHARLES W. CARMAN

INSTRUCTOR.

GRAND RAPIDS, MICH.:
THE DEAN PRINTING AND PUBLISHING CO.
1889.

PREFATORY NOTE.

THESE pages have been printed for the convenience of our own pupils. As it is possible, however, that some other teachers may wish to place them in the hands of their pupils, the following suggestions are offered regarding their use.

The outline has grown from an effort made during the past two years, to change the instruction in physics from the form in which the instructor uses and makes the apparatus, to that in which the pupil, assisted by the instructor, does this part of the work. It is not possible to make a "set of directions" for laboratory work that is adapted to all laboratories. In many respects, however, the directions are the same for all.

The right hand page of the outline has been left blank that the pupil may record such additional exercises and notes as the instructor may wish to give, and that the instructor may make such changes as his judgment may dictate and his laboratory may demand. The first part of each recitation hour is used for this purpose. The exercises are also read in class before the pupils go to the laboratory to perform them, that the instructor may judge regarding the clearness of the pupil's mind with reference to what he is to do. The remainder of the hour is used in questioning the pupil on the exercises previously performed, and in emphasizing the principles involved.

The distinctive feature of the outline is thought to rest upon the idea that the high school laboratory exists as an

aid to getting at the principles of the elements of physics, not as a separate course of instruction. The aim has been, not to give information to pupils, but to direct them how to get it by their own efforts.

It has been urged against this form of instruction that it requires much time on the part of the instructor, and that only a few pupils can be taught at once. During the past two years the writer has given instruction, each year, in five subjects, four of which—physics, chemistry, zoology and geology—have been taught by the laboratory method, each pupil working in the laboratory from half an hour to two hours a day. The average number working in the laboratory daily, during the past year, has been about ninety. This has been made possible by using, as assistants, members of the previous class, elected by their class-mates. The plan has proved highly satisfactory.

DIRECTIONS TO PUPILS.

THERE are many ways of studying Natural Philosophy, or Physics. We may begin by committing to memory facts and laws discovered by others, and by observing what is going on around us.

Another method, the one we shall follow, is to go to our laboratory, and there endeavor to work out the definitions and laws we wish to know, and to observe and think on what is going on in the world around us.

But do not think that going to the laboratory for a given length of time will bring about the desired end. This can be done only by following closely the directions given you, by careful thought on your part, much oral instruction and the assistance of many books.

The following general directions should be read carefully and kept in mind as a part of the special directions that are given you in the following pages.

Recitation Hour.—The recitation hour will be used (1) to give you instruction regarding your work in the laboratory; (2) to question you on the work you have done previously; (3) to discuss the general principles of the subject, and (4) to sum up and review the previous work of the year.

The Laboratory.—It is very important that you remember the laboratory is designed for the accommodation and preservation of the apparatus we use, as well as to serve the purpose of a place in which to use it. The utmost care

must always be taken in moving and manipulating apparatus.

On entering the laboratory, take your place at one of the tables not occupied. Read the directions given you as a guide in performing the exercise for which the apparatus before you has been arranged. Sketch in your "rough note book" the apparatus used. Record your manipulations, observations and conclusions. When the work assigned has been completed, leave the laboratory.

Do not touch apparatus other than that designed for the work of the day. If a piece of apparatus is injured, inform your instructor at once. If you find you are unable to perform an exercise to your satisfaction, do not say to yourself (or to any one else) petulantly, "I can't," or "I do not understand it," but, after having given it careful thought and having made earnest effort, ask your instructor to assist you.

Your deportment in the laboratory must be unexceptionable. Talking or laughing, excess of any form of communication, anything ungentlemanly or unladylike, will render you liable to suspension from the laboratory and class during the remainder of the year. The above and more on this subject may be summed up by saying that *you* know how to conduct yourself, and that suspension will be based upon general, not upon specific directions.

NOTE-TAKING.—Make full notes while in the laboratory. Let neatness, accuracy and judgment be used in revising for your record-book. Let your work, sketches and records be your own. Nothing will lower you in the estimation of your classmates and instructor more than the practice of petty dishonesty.

Give due attention to the sketching of the apparatus. With the assistance you may receive from the drawing-teacher, you will have opportunity to improve rapidly in this part of the work.

REFERENCE ROOM.—Good instruction, both oral and written, are indispensable to rapid progress in your work. In the room adjoining the laboratory you will find your instructor (when not in the laboratory) and the reference books. Do not hesitate to consult either when necessary. If you wish to take a book from the reference room, you may do so by following the directions given there.

The following is a list of some of the books of reference:

ELEMENTARY TEXT BOOKS.

AVERY—Elements of Natural Philosophy.
AVERY—First Principles of Natural Philosophy.
GAGE—Elements of Physics.
GAGE—Introduction to Physical Science.
EVERETT—Outlines of Natural Philosophy.
NORTON—Natural Philosophy.
NORTON—Elements of Physics.
GILLETT & ROLFE—Natural Philosophy.
GILLETT & ROLFE—First Book in Philosophy.
STEELE—New Physics.

LABORATORY BOOKS.

CHUTE—Practical Physics.
WORTHINGTON—Physical Laboratory Practice.
TROWBRIDGE—The New Physics.
WEINHOLD—Elementary Physics.

ADVANCED TEXT BOOKS.

DESCHANEL—Natural Philosophy.
GANOT—Physics.
DANIELL—Text Book of the Principles of Physics.
ANTHONY & BRACKETT—Physics.

LABORATORY BOOKS.

STUART & GEE—Elementary Practical Physics.
PICKERING—Physical Manipulations.
GLAZEBOOK & SHAW—Practical Physics.

(SPECIAL SUBJECTS.)

MECHANICS.

PAICE—Energy and Motion.
WORTHEN—First Lessons in Mechanics.
NYSTROM—Elements of Mechanics.
RANKINE—A Manual of Applied Mechanics.

HEAT.

STEWART—Elementary Treatise on Heat.

MAGNETISM.

THOMPSON S. P.—Electricity and Magnetism.
MAXWELL—Treatise on Electricity and Magnetism.
GORDON—Electricity and Magnetism.
GUTHRIE—Magnetism and Electricity.

ELECTRICITY.

AYRTON—Practical Electricity.
BARNARD—First Steps in Electricity.
GORDON—School Electricity.
NIAUDET—Elementary Treatise on Electric Batteries.

FONTAINE—Electrolyses.

ATKINSON—Elements of Statical Electricity.

THOMPSON, S. P.—Dynamo-Electric Machinery.

DU MONCEL—Electricity as a Motive Power.

DOLBEAR—The Telephone.

PRESCOTT—The Speaking Telephone, Talking Phonograph and Other Novelties.

HOSPITALIER—Modern Applications of Electricity.

HAMMOND—Electric Light in our Homes.

SWINTON—Principles and Practice of Electric Lighting.

SOUND.

TYNDALL—Sound.

MAYER—Sound.

BLASERNA—Theory of Sound.

LIGHT.

DOLBEAR—The Art of Projecting.

MAYER AND BARNARD—Light.

TYNDALL—Light.

TAIT—Light.

SPOTTISWOODE—Polarization of Light.

LOCKYER—The Spectroscope.

NOLAN—The Telescope.

VOGEL—The Chemistry of Light.

ROOD—Modern Chromatics.

POPULAR BOOKS.

ROUTLEDGE—Popular History of Science.

FARADAY—Lectures on the Physical Forces.

FARADAY—On the Various Forces of Nature.

GUILLEMIN—Forces of Nature.

Tyndall--Faraday as a Discoverer.
Radau—Wonders of Accoustics.
Abbott—Light.
Marion—Wonders of Optics.
Cazin—Wonders of Heat.
Fonvielle, de—Thunder and Lightning
Tyndall—Heat as a Mode of Motion.

"FOR REFERENCE."

[Taken from Appleton's Laboratory Yearbook, and the appendix to Questions on Stewart's Physics" by Geo. A. Hill].

ENGLISH WEIGHTS AND MEASURES.

The Imperial Standard Yard is by an Act of Parliament, the distance between two points in a certain bronze bar deposited in the Office of the Exchequer in London, the temperature of the bar being 62° F.

The Imperial Standard Pound Avoirdupois is, by the Act above cited, a platinum weight marked "P. S. 1844, 1 lb.," deposited in the Office of the Exchequer in London.

UNITED STATES WEIGHTS AND MEASURES.

The United States stəndards of lengths and mass are copies of old English standards, and are very nearly the same as the present Imperial standards of Great Brittain.

Careful comparison has shown that the United States actual standard yard (a brass scale made by Troughton of London, in 1813, and deposited in the Office of Weights and Measures in Washington) is equal to 1.000024 Imperial yards, and that the United States actual standard of mass (a Troy pound of brass, made by Kater in 1827 and deposited in the United States Mint), is equal to 0.99999987 Imperial Troy pounds. The same ratio 0.99999986 also exists between the United States and Imperial Avoirdupois pounds.

The United States Gallon, or standard unit of liquid measure, is the old wine gallon of England and contains 231 cubic inches.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

The metre, or standard of length, is the distance between the ends of a certain platinum bar made by Borda, and preserved in the Archives de l'Etat in Paris, the bar being at the temperature of melting ice. The metre was intended to be an exact ten-millionth part of a quadrant of the earth's meridian, but according to the most trustworthy measurements the actual standard metre (Borda's platinum rod) is less than its intended value by an amount not exceeding $\frac{1}{5590}$ of a meter or about $\frac{1}{150}$ of an inch.

The Kilogram, or standard of Mass is the quantity of matter in a certain platinum weight made by Borda, and deposited in the Archives de l'Etat in Paris. It was intended to be (and is very nearly) equal to the mass of one cubic decimetre of distilled water at the point of maximum density (about 4° C).

The metre and kilogram derive their authority as standards from a law of the French Republic in 1795. Of the prototype standards, kept at Paris, numerous copies have heen taken which, after having been compared with the originals with the utmost precision of which modern science is capable, have been made standards of reference and verification in the various countries in which the Metric System has been adopted.

The Metric System of Weights and Measures is a system in the true sense of that word, and the simple mode is which all the other units are derived from the standards is

in striking contrast with the want of system and troublesome numerical relations existing in English Weights and Measurers.

Nearly all the derived units in the Metric System are obtained by the application of two very simple principles, viz., decimal multiplication and division, and the use of squares and cubes of linear units as units of surface and volume respectively. Hence each unit of length and also of mass is 10 times as large as the next smaller unit in order, each unit of surface 100 times as large, each unit of volume, 1000 times.

Names for all the units are formed from the roots of metre and grams, by employing Greek prefixes, deca (10), hecto (100), kilo (1000), for the multiples and the Latin prefixes, deci (0.1), centi (0.01), milli (0.001) for the sub-multiples. In the measures of surface and of volume, the words square and cubic respectively are also employed. Thus, 1 centimetre is equal to 0.01 of a metre, 1 cubic centimetre is equal to 0.001 of a cubic metre, 1 kilogram is equal to 1000 grams, etc.

TABLE

OF WEIGHTS AND MEASURES IN THE METRIC SYSTEM.

MEASURES OF			
LENGTH.	SURFACE.	VOLUME.	MASS.
10.	100.	1000.	10.
Kilometre (km).....	Sq. kilometre (km^2).....	Cubic kilometre (km^3)..	Kilogram (kg)....
Hectometre (hm)....	Sq. hectometre (hm^2)...	Cubic hectometre (hm^3).	Hectogram (hg)..
Decametre (dcm) ...	Sq. decametre (dcm^2)...	Cubic decametre (dcm^3).	Decagram (dcg)..
Metre (m)..........	Sq. metre (m^2)..........	Cubic metre (m^3).......	Gram (g).........
Decimetre (dm).....	Sq. decimetre (dm^2)....	Cubic centimetre (cm^3).	Decigram (dg) ...
Centimetre (cm)	Sq. centimetre (cm^2)....	Cubic decimetre (dm^3)..	Centigram (cg)...
Millimetre (mm)....	Sq. millimetre (mm^2)...	Cubic millimetre (mm^3).	Milligram (mfi)...
The number at the head of each column denotes the ratio of any unit in that column to the unit next below it.			Tonne=1000 kilograms.

TABLE

OF RELATIVE VALUES OF ENGLISH AND METRIC MEASURES.

English in Metric.	Value.	Metric in English.	Value.
1 English inch in centimeters..	2.5399772	1 centimetre in English inches .	0.39370421
1 English foot in metres.......	0.30479727	1 metre in English feet.........	3.28086983
1 English yard in metres......	0.91439180	1 metre in English yards.......	1.09362311
1 English statute mile in kilometre..................	1.6093295	1 kilometre in English statute miles....................	0.61237677
1 square foot in centiares......	0.09280137	1 centiare in in square feet.....	10.764104
1 acre in hectares............	0.4046783	1 hectare in acres..............	2.4710982
1 square mile in hectares......	258.99416	1 hectare in square miles.......	0.00386109
1 cubic foot in cubic metre (steres)................	0.02831608	1 cubic metre in cubic feet.....	35.315617
1 cord in steres................	3.6244589	1 stere in cords................	0.2759033
1 Imperial gallon in litres......	4.5435845	1 litre in Imperial gallons......	0.2200906
1 U. S. gallon in litres.........	3.785	1 litre in U. S. gallons.........	0.264
1 U. S. bushel in litres........	35.24	1 lttre in U. S. bushels.........	0.02838
1 Imperial quart in litres	1.1358961	1 litre in Imperial quarts.......	0.8803624
1 U. S. liquid quart in litres...	0.94625	1 litre in U. S. liquid quarts....	1.056
1 U. S. dry qurt in litres.......	1.10125	1 litre in U. S. dry quarts......	0.90816
1 grain in grams	0.0647989	1 gram in grains...............	15.4324874
1 pound (Avor.) in kilograms ..	0.54359265	1 kilogram in pounds (Avoir....	2.20462125
1 pound (Troy) in kilograms...	9.37324196	1 kilogram in pounds (Troy)....	2.67922721
1 foot pound (Avoir.) in kilometres.................	0.1382538	1 kilogram metre in foot p'nds (Avoir)..................	7.2330743

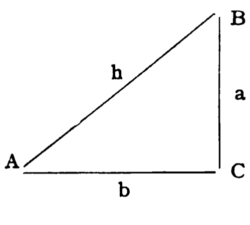
MATHEMATICAL DATA AND FORMULAS.

GEOMETRY.

π (ratio of circumference of circle to diameter) $= 3.14159$
Circumference of a circle (radius r) $= 2\pi R$
Area of circle (radius r) $= \pi r^2$
Surface of a sphere (radius r) $= 4\pi r^2$
Surface of an ellipse (semi-axes a and b) $= \frac{\pi a b}{4}$
Surface of right cylinder (height h, base πr^2) $= 2\pi r h + 2\pi r^2$
Surface of right cone (height h, base πr^2) $= \pi r^2 + 2\pi r \tfrac{1}{2} s l$
Volume of a sphere (radius r) $= \tfrac{4}{3}\pi r^3$
Volume of ellipse (semi-axes a, b and c) $= \tfrac{3}{4}\pi a b c$
Volume of right cylinder (height h, base πr^2) $= \pi r^2 h$
Volume of right cone (height h, base πr^2) $= \tfrac{1}{3}\pi r^2 h$
Sum of three angles of a triangle $= 180^\circ$
Area of a triangle of altitude h base b $= \tfrac{1}{2} b h$

Two triangles which have equal bases and equal altitudes are equal.

PLAIN TRIGONOMETRY.



Definitions of the functions of an angle:

Let h denote the hypothenuse of a right angled-triangle, a the perpendicular, b the base, A and B the angles opposite a and b respectively; then—

$$\begin{cases} \sin A = \frac{a}{h}. \quad \tan A = \frac{a}{b}. \quad \sec A = \frac{h}{b}. \\ \cos A = \frac{b}{h}. \quad \cot A = \frac{b}{a}. \quad \operatorname{cosec} A = \frac{h}{a}. \end{cases}$$

VALUES

OF THE FUNCTIONS OF PARTICULAR ANGLES.

ANGLE.	ARC.	SIN.	COS.	TAN.	COT.	SEC.	COSEC.
$0°$	0	0	1	0	∞	1	∞
$30°$	$\frac{1}{6}\pi$	$\frac{1}{2}$	$\frac{1}{2}(3)^{\frac{1}{2}}$	$(\frac{1}{3})^{\frac{1}{2}}$	$(3)^{\frac{1}{2}}$	$2(\frac{1}{3})^{\frac{1}{2}}$	2
$45°$	$\frac{1}{4}\pi$	$(\frac{1}{2})^{\circ}$	$(\frac{1}{2})^{\frac{1}{2}}$	1	1	$(2)^{\frac{1}{2}}$	$(2)^{\frac{1}{2}}$
$60°$	$\frac{1}{3}\pi$	$\frac{1}{2}(3)^{\frac{1}{2}}$	$\frac{1}{2}$	$(3)^{\frac{1}{2}}$	$(\frac{1}{3})^{\frac{1}{2}}$	2	$2(\frac{1}{3})^{\frac{1}{2}}$
$90°$	$\frac{1}{2}\pi$	1	0	∞	0	∞	1
$120°$	$\frac{2}{3}\pi$	$\frac{1}{2}(3)^{\frac{1}{2}}$	$-\frac{1}{2}$	$-(3)^{\frac{1}{2}}$	$-(\frac{1}{3})^{\frac{1}{2}}$	-5	$2(\frac{1}{3})^{\frac{1}{2}}$
$135°$	$\frac{3}{4}\pi$	$(\frac{1}{2})^{\frac{1}{2}}$	$-(\frac{1}{2})^{\frac{1}{2}}$	-1	-1	$-(2)^{\frac{1}{2}}$	$(2)^{\frac{1}{2}}$
$150°$	$\frac{5}{6}\pi$	$\frac{1}{2}$	$-\frac{1}{2}(3)^{\frac{1}{2}}$	$-(\frac{1}{3})^{\frac{1}{2}}$	$-(3)^{\frac{1}{2}}$	$-2(\frac{1}{3})^{\frac{1}{2}}$	2
$180°$	π	0	-1	0	∞	-1	∞

$$\sin^2 a + \cos^2 a = 1$$

$$\tan a = \frac{\sin a}{\cos a} = \frac{1}{\cot a}$$

$$\sec^2 a = 1 + \tan^2 a$$

$$\text{cosec}^2 a = 1 + \cot^2 a$$

$$\text{versed} \sin a = - \cos a$$

$$\sin {}^2a = 2 \sin a \cos a$$

$$\cos 2a = \cos {}^2a - \sin {}^2a$$

$$\tan {}^2a = \frac{2 \tan a}{1 - \tan 2 a}$$

$$\sin (a \pm B) = \sin a \cos B \pm \cos a \sin B$$

$$\cos (a \pm B) = \cos a \cos B \pm \sin a \sin \mathrm{B}$$

$$\tan (a \pm B) = \frac{\tan a \pm \tan B}{1 \pm \tan a \tan B}$$

$$\cot (a \pm B) = \frac{\cot B \cot a \pm 1}{\cot B \pm \cot a}$$

$$\sin a + \sin b = 2 \sin \tfrac{1}{2} (a + B) \cos \tfrac{1}{2} (a - B)$$
$$\sin a - \sin b = 2 \cos \tfrac{1}{2} (a + B) \sin \tfrac{1}{2} (a - B)$$
$$\cos a + \cos b = 2 \cos \tfrac{1}{2} (a + B) \cos \tfrac{1}{2} (a - B)$$
$$\cos a - \cos b) = - 2 \sin \tfrac{1}{2} (a + B) \sin \tfrac{1}{2} (a - B)$$

in any plane triangle, let a, b, c, denote the sides, A, B, C, the angles respectively the angles opposite the sides and let $s = \tfrac{1}{2} (a + b + c)$; then,—

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$\frac{a + b}{a - b} = \frac{\tan \tfrac{1}{2} (A + B)}{\tan \tfrac{1}{2} A - B)}$$

$$\begin{cases} a^2 = b^2 + c^2 - 2\, b\, c \cos A. \\ b^2 = c^2 + a^2 - 2\, c\, a \cos B \\ c^2 = b^2 + a^2 - 2\, a\, b \cos C. \end{cases}$$

$$\sin \tfrac{1}{2}\, a = \sqrt{\frac{(s - b) (- c)}{b\, c}}$$

$$\cos \tfrac{1}{2}\, a = \sqrt{\frac{s\,(s - a)}{b\, c}}$$

$$\tan \tfrac{1}{2}\, a = \sqrt{\frac{(s - b)\,(s - c)}{s\,(s - a)}}$$

DIMENSIONS OF DYNAMICAL UNITS

T denoting a time, L a length, M a mass.

	Velocity	Acceleration	Momentum	Force	Energy
DIMENSION...........	$\frac{L}{T}$	$\frac{L}{T^2}$	$\frac{M\,L}{T}$	$\frac{M\,L}{T^2}$	$\frac{M\,L^2}{T^2}$

mass × velocity = mass × acceleration × time = force × time

Specific Gravity of Solids and Liquids, referred to that of Distilled Water at 4° C. as a standard.

METALS.

Platinum, hammered	22.060	Iron, wrought	7.780
Gold	19.350	Steel, soft	7.830
Silver	10.510	Steel, tempered	7.810
Copper	8.900	Brass, cast	7.820
Lead, cast	11.350	Brass, sheet	8.390
Tin, cast	7.290	Bronze, statuary	8.950
Zinc	7.190	Bronze, gun metal	8.460
Iron, cast	7.250	Aluminum	2.600

WOODS.

Lignum Vitae	1.333	Ash	0.845
Box, Dutch	1.328	Maple	0.790
Box, French	0.912	Elm	0.673
Ebony, American	1.331	Chestnut	0.565
Oak, just felled	1.113	Red Pine	0.657
Oak, seasoned	0.743	White Pine	0.551
Mahogany, Spanish	1.063	Larch	0.530
Beech	0.852	Cork	0.240

ROCKS.

Granite	2.65 to 2.75	Slate	2.84
Sandstone	2.35 to 2.65	Porcelain Clay	2.21
Limestone	2.60 to 2.70	Sand, dry	1.42
Marble	2.65 to 2.75		

VARIOUS SUBSTANCES.

Diamond	3.530	Coal, anthracite	1.800
Glass, flint	3.000	Coal, bituminous	1.270

Glass, crown	2.520	Wax	0.960
Sulphur	2.086	Ice	0.918
Brick	2.000		

LIQUIDS.

Mercury	13.596	Milk	1.031
Bromine	2.966	Seawater	1.025
Sulphuric Acid, commercial	1.841	Proof Spirit	0.920
Nitric Acid, commercial	1.500	Absolute Alcohol	0.795
Muriatic Acid, commercial	1.200	Sulphuric Ether	0.715
Chloroform	1.492	Olive Oil	0.915
		Oil of Turpentine	0.870
		Naptha	0.840

Specific gravities of gases and vapors, referred to that of dry air, at the same temperature and pressure as the standard.

Oxygen	1.106	Vapor of Water	0.623
Hydrogen	0.069	Carbonic Oxide	0.967
Nitrogen	0.972	Carbonic Acid	1.525
Chlorine	2.470	Ether	2.570
Ammonia	0.590	Marsh Gas	0.555
Nitrous Oxide	1.520	Coal Gas	0.420 to 0.520

Weight of one litre of dry air at 0° C., and 76 centimetres pressure at Paris = 1.293 grams weight of one cubic foot of dry air at 32° F. and 29.905 inches pressure at London — 565 grains, or about 1.25 ounces avoirdupois.

BAROMETERIC FORMULAS FOR FINDING DIFFERENCE OF LEVEL.

In these formulas X denotes difference of level, h height of barometer at lower station reduced to 0° C., h' the same for higher station, t the temperature at lower station, t' the same for higher station t and t' being expressed in Fahrenheit in I. and in Centigrade in II., λ the latitude of the stations. The atmosphere is supposed to be in a mean hygrometric condition. The second and simpler value of X, given both in I. and II., will suffice for heights not exceeding 3300 feet or 1000 metres.

I.

$$X \text{ (in feet)} = 60384 \log. \frac{h}{h'}\left[1 + \frac{t + t' - 64}{900}\right] \times$$
$$1 + 0.00256 \cos 2\lambda$$
$$= 52500 \frac{h - h'}{h + h'}\left[1 + \frac{t + t' - 64}{900}\right]$$

II.

$$X \text{ (in metres)} = 18400 \log \frac{h}{h'}\left[1 + \frac{2(t + t')}{1000}\right] \times$$
$$1 + 0.00256 \cos 2\lambda$$
$$= 16000 \frac{h - h'}{h + h}\left[1 + \frac{2(t + t')}{1000}\right]$$

ALPHABETICAL TABLE OF EQUIVALENT VALUES OF WEIGHTS AND MEASURES.

1 Are = 100 sq. metres, 119.6 sq. yds.

1 Centaire = 1 sq. metre = 100 sq. centimeters, 1550 square inches.

1 Centimetre = 1-100 of a metre, .3937 inches.

1 cubic centimetre (of distilled water) = 1 gram, .0610 cubic inches.

1 cubic decimeter (same as 1 litre) 1000 [$c\ m^3$].

1 cubic decimetre of distilled water, weighs 1000 grams, 1 kilogram.

1 cubic decimetre in English or Imperial measure, .8804 qts.

1 cubic decimetre in American or wine measure, 1.0567 quarts.

1 cubic foot (1728 cubic inches) 28,315.31.9 [c m3].

1 cubic foot of water (at 62 F.) weighs 62.3210 lbs. av.

1 cubic inch 16.3861 [c m3].

1 cubic inch of water (at 60° F.) weighs 252.5 grains.

1 cubic inch of water (at 62° F.) weighs 252.458 grains.

1 cubic metre (1 stere) = 1,000,000 c. c. or 1.000 litres.

1 fluid oz. imperial = 28.4 c. c. 1.7329 cu. inches.

1 fluid oz. wine measure = 29.5 c. c. 1.8047 cu. inches.

1 fluid oz. imperial of water (62° F.) 437.5 grains.

1 fluid oz. wine measure of water (60° F.) weighs 456.0 grains.

1 foot, 30.48 centimetres.

1 gallon imperial = 277.274 cu. inches 4.7852 litres

1 gallon imperial of water weighs (62° F.) 10 lbs. or 70,000 grains.

1 gallon wine measure = 231 cu. inches, 3.7852 litres.

1 gallon wine measure of water weighs (60° F.) 8.34 lbs. = 58372.2 grs.

1 grain (weight of 1 c. c. of dist. water 4° C.) 15.4323 grains.

1 inch 2.54 centimetres.

1 kilogram (1000 grains) 2.2046 lbs. avoir.

1 litre (see cubic decimetre.)

1 metre (140 mill'nth of earth's meridian) 3 ft. 3 and 3/8 in.; 39.3708 inches.

1 pint, wine measure = 16 fluid oz. = of water (60° F.) 7296.5 gr. = 473.148 [c m^3].

1 pint imperial = 20 fluid oz. = of water (62° F.) 8750 gr. = 567.932 [c m^3].

1 quart, wine measure = 32 fluid oz. .9463 litres.

1 quart, imperial = 40 fluid oz. 1.1358 litres.

1 ton avoirdupois (2,000 lbs.) 29166⅔ oz. Troy.

1 tonnean 1,000,000 grns. 1,000 kilo's.

TABLE

SHOWING CORRESPONDING DEGREES ON THE SCALES OF THE FAHRENHEIT AND CENTIGRADE THERMOMETERS.

FAHR	CENT.	FAHR.	CENT.	FAHR.	CENT.	FAHR.	CENT.	FAHR.	CENT.	FAHR.	CENT.
32...	0.	62....	16.6	91.4.	33.	121...	49.4	152...	66.6	182...	83.3
33...	.5	62.2..	17	92...	33.3	122...	50.	152.6.	67.	183...	83.8
33.8.	1.	63....	17.2	93...	33.8	123...	50.5	153...	67.2	183.2.	84.
34...	1.1	64....	17.7	93.2.	34.	123.8.	51.	154...	67.7	184...	84.4
35...	1.6	64.4..	18	94...	34.4	124...	51.1	154.4.	68.	185...	85.
35.6.	2.	65....	18.3	95...	35.	125...	51.6	155...	68.3	186...	85.5
36...	2.2	66....	18.8	96...	35.5	125.6.	52.	156...	68.8	186.8.	86.
37...	2.7	66.2..	19	96.8.	36.	126...	52.2	156.2.	69.	187...	86.1
37.4.	3.	67....	19.4	97...	36.1	127...	52.7	157...	69.4	188...	86.6
38...	3.3	68....	20	98...	36.6	127.4.	53.	158...	70.	188.6.	87.
39...	3.8	69....	20.5	98.6.	37.	128...	53.3	159...	70.5	189...	87.2
39.2.	4.	69.8..	21	99...	37.2	129...	53.8	159.8.	71.	190...	87.7
40...	4.4	70....	21.1	100...	37.7	129.2.	54.	160...	71.1	190.4.	88.
41...	5.	71....	21.6	100.4.	38.	130...	54.4	161...	71.6	191...	88.3
42...	5.5	71.6..	22	101...	38.3	131...	55.	161.6.	72.	192...	88.8
42.8.	6.	72....	22.2	102...	38.8	132...	55.5	162...	72.2	192.2.	89.
43...	6.1	73....	22.7	102.2.	39.	132.8.	56.	163...	72.7	193...	89.4
44...	6.6	73.4..	23	103...	39.4	133...	56.1	163.4.	73.	194...	90.
44.6.	7.	74....	23.3	104...	40.	134...	56.6	164...	73.3	195...	90.5
45...	7.2	75....	23.8	105...	40.5	134.6.	57.	165...	73.8	195.8.	91.
46...	7.7	75.2..	24	105.8.	41.	135...	57.2	165.2.	74.	196...	91.1
46.4.	8.	76....	24.4	106...	41.1	136...	57.7	166...	74.4	197...	91.6
47...	8.3	77....	25	107...	41.6	136.4.	58.	167...	75.	197.6.	92.
48...	8.8	78....	25 5	107.6.	42.	137...	58.3	168...	75.5	198...	92,2
48.2.	9.	78.8..	26	108...	42.2	138...	58.8	168.8.	76.	199...	92.7
49...	9.4	79....	26.1	109...	42.7	138.2.	59.	169...	76.1	199.4.	93.
50...	10.	80....	26.6	109.4.	43.	139...	59.4	170...	76.6	200...	93.3
51...	10.5	80.6..	27	110...	43.3	140...	60.	170.6.	77.	201...	93.8
51.8.	11.	81....	27.2	111...	43.8	141...	60.5	171...	77.2	201.2.	94.
52...	11.1	82....	27.7	111.2.	44.	141.8.	61.	172...	77.7	202...	94.4
53...	11.6	82.4..	28	112...	44.4	142...	61.1	172.4.	78.	203...	95.
53.6.	12.	83....	28.3	113...	45.	143...	61.6	173...	78.3	204...	95.5
54...	12.2	84....	28.8	114...	45.5	143.6.	62.	174...	78.8	204.8.	96.
55...	12.7	84.2..	29	114.8.	46.	144...	62.2	174.2.	79.	205...	96.1
55.4.	13.	85....	29.4	115...	46.1	145...	62.7	175...	79.4	206...	96.6
56...	13.3	86....	30	116...	46.6	145.4.	63.	176...	80.	206.6.	97.
57...	13.8	87....	30.5	116.6.	47.	146...	63.3	177...	80.5	207...	97.2
57.2.	14.	87.8..	31	117...	47.2	147...	63.8	177.8.	81.	208...	97.7
58...	14.4	88....	31.1	118...	47.7	147·2.	64.	178...	81.1	208.4.	98.
59...	15.	89....	31.6	118.4.	48.	148...	64.4	179...	86.6	209...	93.3
60...	15.5	89.6..	32	119...	48.3	149...	65.	179.6.	82.	210...	98.8
60.8.	16.	90....	32.2	120...	48.8	150...	65.5	180...	82.2	210.2.	99.
61...	16.1	91....	32.7	120.2.	49.	150.8.	66.	181...	82.7	211...	99.4
.....	....	....	....	....	....	151...	66.1	181.4.	83.	212...	100.

THE C. G. S. SYSTEM OF UNITS.

The C. G. S. System of Units is the result of an attempt to express all quantities with which physical science deals in terms of three fundamental units:—

A Unit of Length—The centimetre.

A Unit of Mass—The gram.

A Unit of Time—The second.

From these, the following units are derived:—

Unit of Surface—The square centimetre.

Unit of Volume—The cubic centimetre.

Unit of Velocity—The velocity of one centimetre per second.

Unit of Acceleration—The acceleration which imparts unit velocity to a body in one second.

Unit of Force—The dyne; the force, which, acting on a gram mass for one second, imparts to it a unit of velocity.

Unit of Work—The erg; the work done by a dyne, working through one centimetre.

Unit of Energy—Also the erg; since the energy of a body is measured by the amount of work it can do.

Unit of Heat—The amount of heat required to raise one gram of water from 0° to 1° C.

Unit of Magnetic Strength—A magnetic pole has unit strength when it repels a similar pole of equal strength, one centimetre distant, with the force of a dyne.

Unit of Electric Current (electro-magnetic system)—A current of such strength that one centimetre of its circuit, bent so that every point of it is one centimetre distant from a unit magnetic pole, exerts upon this pole the force of a dyne.

Unit of Electric Quantity (electro-magnetic system)—The quantity conveyed by a unit current in one second.

Unit of Difference of Potential (electro-magnetic system)—Two points have unit difference of potential when one erg of work must be expended to bring a unit of + electricity from one to the other against the electric force.

Unit of Electric Resistance (electro-magnetic system)—A conductor possesses unit resistance when a unit difference of potential between its ends, causes a unit current to flow through it.

ALPHABETICAL TABLE OF UNITS USED IN PHYSICAL SCIENCE.

Ampere—Unit of electric current; 10^{-1} C. G. S. Units; the current produced by the difference of potential of a volt through the resistance of an ohm.

Calorie—French unit of heat; quantity of heat required to raise one kilogram of water from 0° to 1° C; equals 3.968 English units of heat. (See Heat, English unit of) Capacity, unit of electric. See Farad.

Cheval-de-vapeur. See Force-de-cheval.

Coulomb—Unit of electric quantity; 10^{-1} C. G. S. units; quantity conveyed by the current of an ampere in a second Current, unit of electric: See Ampere.

Electro-motive force, unit of. See Volt.

Farad—Unit of electric capacity; 10^{-9} C. G. S. units; quantity which, with the electro-motive force of a volt, would flow through the resistance of an ohm in one second.

Foot-pound—English unit of work; work required to raise one pound through one foot in opposition to the force of gravity.

Force—Units of. See Kilogram and Pound.

Force-de-cheval—French unit of power; .9864 horse-power; power of doing 75 kilogram-metres (542.5 foot-pounds of work per second.)

Heat—English unit of; heat required to raise one pound of water from 32° to 33° F. (See Calorie).

Horse-power—English unit of power; power required to perform 550 foot pounds of work per second.

Kilogram—French unit of mass, and also of force. (See pound).

Kilogrammetre—French unit of work; work required to raise one kilogram of mass through one metre in opposition to force of gravity.

Mass—Units of. See Kilogram and Pound.

Ohm—Unit of electric resistance; 10^9 C. G. S. units is the resistance offered to a current of electricity by a wire of pure silver or copper one millimetre in diametre and 48.61 metres long at 65° *F* (18.3° C.).

Potential—Unit difference of. See Volt.

Pound—English unit of mass; regarded as a weight it is also used as the unit of force, i. e. the force exercised by the mass of a pound (where $g = 981$: London).

Power—Unit of. See Force-de-cheval and Horse-power.

Power—Unit of electric. See Watt.

Quantity—Unit of electric. See Coulomb.

Quantity—Unit of magnetic. See Weber.

Resistance—Unit of electric. See Ohm.

Volt—Unit of electro-motive force; 10^8 C. G. S. Units; equals .9268 of the force of one Daniell cell.

Watt—Unit of electric power; 10^7 C. G. S. units; power exerted by the current of an ampere through the difference of a potential volt.

Weber—Unity of magnetic quantity; 10^8 C. G. S. units.

Work—Units of. See Foot-pound and Kilogrammetre.

CHAPTER I.

MATTER AND ITS PROPERTIES.

SECTION 1.

UNIVERSAL PROPERTIES.

1. EXTENSION.

MEASUREMENT OF LENGTH.—Review the Metric and English Systems of Weights and Measures.

See Olney's Arith.; Avery,* Art. 26; Gage,* pp. 399-401; Stuart and Gee, Art. 1-3; "For Reference" (above); The diagonal scale, explained; The Vernier, explained; Stuart and Gee, Art. 9.

EXERCISE 1. Determine the length and width of one of the laboratory tables, using your ruler and metre stick. Make three measurements in each case, and take the average as your final result. Use both the Metric and English Systems. Tabulate and compare your results.

EXERCISE 2. Determine, as above, the length and diameter of one of the iron rods you will find on the laboratory table, using your dividers, diagonal scale and the steel scale which you will find in the laboratory.

*The reference "Avery" or "Gage" means Avery's Elements of Natural Philosophy, last edition, or Gage's Elements of Physics.

EXERCISE 3. Determine, as above, the length, width, and thickness of one of the iron bars on the table.

EXERCISE 4. Determine the distance between two points which you may designate on the table.

EXERCISE 5. Construct a Vernier scale.

See Stuart and Gee, p. 8; Trowbridge, p. 40, Exp. 37.

EXERCISE 6. Repeat the measurements made in exercises 2 and 3, using the Vernier you have constructed.

EXERCISE 7. Read the Vernier on the Barometer.

NOTE.—When you are prepared for this exercise, ask your instructor to show you how to manipulate the barometer. Do not touch it until you have received such instruction.

EXERCISE 8. Determine the diameters of several pieces of wire by means of the Micrometer Wire Gauge.

NOTE.—Ask your instructor for this piece of apparatus, and how to use it.

EXERCISE 9. Determine the thickness of a thin piece of glass by means of the Spherometer.

See note above.

EXERCISE 10. Measure the diameter and circumference of a circle, and determine the ratio between them. Verify your results by repeating the exercise with at least three circles of different sizes.

INSTRUCTIONS. From stiff card-board, cut three circles of varying sizes. Draw a straight line through the centres of the circles, and also upon a page of your note-book. Cause the circles to roll along the straight line and measure the spaces passed over. Measure the diameters of the circles. You should be able to complete the exercise with-

out further instruction. How does the ratio obtained differ from that you ought to obtain? What is the probable cause of the error?

NOTE.—Preserve the circles for future experiment.

EXERCISE 11. Determine the diameter and depth of a cylindrical jar, using the "Callipers." See Stuart and Gee, (Art. 27), diagonal scale, and dividers.

ANGULAR MEASUREMENT.

See Stuart and Gee, Art. 37–43.

EXERCISE 12. With two of the circles prepared in exercise 10, construct a circular vernier.

INSTRUCTIONS. Place the smaller of the two circles upon the larger. Fasten the centres together by means of a rivet. Divide a portion of the larger circle into degrees and minutes of arc. Construct a vernier upon the smaller circle.

See Stuart and Gee, Art. 42.

EXERCISE 13. To read the Verniers on the Spectro-Goniometer.

See note to exercise 8.

MEASUREMENT OF AREA.

TABLE.

Triangle	= Base × ½ perpendicular.
Circle	$= \pi r^2$ when r = radius and $\pi = 3.14159$
Ellipse	$= \frac{\pi}{4} a b$ where a = major, and b minor axis.
Whole surface of right cylinder	$= 2 \pi r b + 2 \pi r^2$ when b = length, and r = radius of cylinder.
Whole surface of right cone	$= \pi r_2 + 2 \pi r \times \frac{1}{2}$ slant height, where r = radius of base.

EXERCISE 14. Determine the area of one of the laboratory tables, using, as data, the measurements previously made.

EXERCISE 15. Determine the whole area of the bar of iron previously measured.

EXERCISE 16. Determine the areas of three triangles, (a right angled, an equilateral, and an isosceles,) cut from cardboard.

EXERCISE 17. Determine the whole area of the iron rod previously measured.

EXERCISE 18. Determine the whole surface of a right cone.

EXERCISE 19. Determine the area of an ellipse, cut from cardboard.

EXERCISE 20. Determine the area of one of the wooden balls provided you.

MEASUREMENT OF VOLUME.

See Stuart and Gee, Art. 74–78.

TABLE.

Cylinder	$= \pi r^2 l$, where r = radius, l = length.
Sphere	$= \frac{4}{3} \pi r^3$, where r = radius.
Cone or Pyramid	= Area of base × ⅓ (vertical height.)

EXERCISE 21. Determine the volume of the square tin dish, having one side glass, furnished you.

EXERCISE 22. Determine the volume of the wooden cube furnished you.

EXERCISE 23. Determine the volume of the "die" furnished you.

EXERCISE 24. Determine the volume of the bar of iron previously measured.

EXERCISE 25. Determine the volume of the tin cylindrical vessel furnished you.

EXERCISE 26. Determine the volume of the iron rod previously measured.

EXERCISE 27. Determine the volume of the wooden ball furnished you.

EXERCISE 28. Fill the tin vessel, used in exercise 21, with water. Open the faucet and allow the water to run into a "graduated cylinder." How do the results obtained by the two methods compare?

EXERCISE 29. Repeat exercise 28, using the tin cylinder of exercise 25. How do your results compare?

EXERCISE 30. Determine the volume of the glass cylindrical vessel furnished you, using the callipers to assist you in making your measurements. Determine the volume by filling the vessel with water from a "burette." How do the results compare?

2. WEIGHT.

See Avery, Art. 34–37; Trowbridge, p. 355, Table 1, and p. 6, experiment 7; Stewart and Gee, Par. 102.

EXERCISE 31. Determine the accuracy of the "Jolly Balance" provided you, by means of the weights with the "Specific Gravity Balance," and enter any corrections necessary in your notes.

EXERCISE 32. With the "Jolly Balance," determine the average weights of several screws, nails, or similar bodies.

EXERCISE 33. Determine the weight of chalk used in writing your name.

INSTRUCTIONS. Weigh a piece of chalk carefully, as above; write your name on the blackboard, weigh again.

EXERCISE 34. Wash thoroughly, at the sink, a piece of copper. Remove the moisture and weigh carefully. Return to the sink and pour half a [$cm.^3$] of nitric acid [$H\ N\ O_3$] upon it. After the chemical action has nearly ceased, wash thoroughly, and, having removed the moisture, weigh again. What is the difference in the two weights?

NOTE.—Whenever directions are given to use an acid or any chemical, do so with the utmost care. It is very easy to injure your clothing and yourself. The first time you use an acid, ask your instructor to assist you.

EXERCISE 35. Weigh, carefully, the cylinderical glass vessel used in exercise 30. Fill it with water measured in a burette and record the capacity of the vessel. Weigh again. What is the weight of the water?

EXERCISE 36. Using the "Specific Gravity Balance," determine the weight of the water that the square tin vessel, used in exercise 28, will hold.

EXERCISE 37. With the same balance as above, determine the weight of the water, that the cylindrical tin vessel, used in exercise 25, will hold.

EXERCISE 38. As above, determine the weight of the water that the litre flask, furnished you, will hold.

EXERCISE 39. As above, determine the weight of the water that the several generating flasks, furnished you, will hold.

RELATIVE WEIGHTS, RELATIVE DENSITIES OR SPECIFIC GRAVITIES.

See Avery, Art. 2; Webster Dictionary, Def. Mass; Stuart and Gee, Art. 82, par 3 to line 5; Avery, Arts. 241 and 242.

EXERCISE 40. Fill the glass vessel, used in exercise 34, with fine shot. Weigh and determine how many times greater is the weight of the shot than the weight of the same volume of water. What is the relative density? What is the Sp. Gr. of the shot?

EXERCISE 41. As above, determine the Sp. Gr. of alcohol, benzine, ether, chloroform, glycerine, sulphuric acid, nitric acid, hydrochloric acid, oil of turpentine, linseed oil, olive oil and mercury.

NOTE.—In using the acids given above, do so with the utmost care. Do not allow a drop to touch your clothes, skin, or any of the apparatus excepting glass. The same precautions may be given regarding mercury; excepting that it is not injurious to the clothes and skin. When your laboratory work requires the use of mercury, leave your gold rings and watch at home, or with a companion.

EXERCISE 42. Determine the Sp. Gr. of alcohol, using the "Specific Gravity Bottle" furnished you.

See Avery, Art. 246.

EXERCISE 43. (*a*). Determine the Sp. Gr. of a small piece each of brass, iron, antimony, lead, platinum, quartz, zinc, and glass.

INSTRUCTIONS. Weigh the substance in air. Partly fill a graduated cylinder with water. Note the height at which the water stands. Now attach a thread to the substance and lower it into the graduate. Note again the height at

which the water stands. A little thought on your part will enable you to complete the exercise.

(*b*). Verify "Archimedes Principle" by experiment with the apparatus furnished you. See Avery, Art. 238.

EXERCISE 44. Determine the Sp. Gr. of the solids given above by another method.

INSTRUCTIONS. Weigh the substance in air. Suspend it from the bottom of the scale pan by means of a fine silk thread, and weigh the body, immersed in water. A little thought on your part will enable you to complete the exercise.

EXERCISE 45. Determine the Sp. Gr. of substances lighter than water, as the following: Cork, pine, oak, etc.

INSTRUCTIONS. Weigh the cork and a sinker in air. Weigh the same in water. Weigh the sinker in air and then in water. A little thought ought to enable you to complete the exercise.

NOTE.—You will find further instructions on this exercise in many of the reference books, but you should be sufficiently self-reliant not to avail yourself of them. If you have received further assistance state the fact at the close of the record of this exercise.

NOTE 2.—For method of finding Sp. Gr. of gases, see Avery, Art. 248; Stuart and Gee, Arts. 210–211.

HYDROMETERS.

See Avery, Arts. 249–250.

EXERCISE 46. Determine the Sp. Gr. of several pieces of metal by means of Nicholson's Hydrometer.

EXERCISE 47. Determine the quality of the alcohol used in the laboratory by means of the alcoholmeter.

Exercise (optional.) To determine the Sp. Gr. of several of the liquids given above, using the "Troemner Balance" and the Sp. Gr. bottle.

NOTE.—Only those who have shown themselves exceptionally careful and expert with apparatus, will be allowed to perform the work in this exercise, since this balance is very delicate and easily injured.

3. DIVISIBILITY.

See Avery, Art. 41.

EXERCISE 48. Place a piece of white paper on the table. Provide yourself with a file and fragments of several substances, such as copper, iron, lead, wood, chalk, granite, quartz, etc. Hold each over the paper and draw a file across it. What are the different results? Try rubbing one upon the other. What is the result?

EXERCISE 49. Weigh a small piece of copper with the Sp. Gr. balance. Drop three or four drops of nitric acid [$H N O^3$] on the copper. After the chemical action has ceased, wash it in 500 [$cm.^3$] of water. Add 2 [$cm.^3$] of ammonia [$N H_3$]. Assuming that the copper, washed from the strip, is equally distributed through the water, what will be the amount in one-tenth of a [cm^3]?

4. ELASTICITY.

See Avery, Art. 45; Stewart and Gee, Arts. 113–114, Par. 1.

EXERCISE 50. Determine which one of the following substances most nearly returns to its original form after you have stretched, bent, or compressed it. A strip of whalebone, rubber, copper, or lead?

EXERCISE 51. Determine which of the following rebound farthest when dropped upon a large piece of iron or marble: A ball of wood, iron, lead, rubber or ivory.

EXERCISE 52. Suspend from one of the side cases, or other convenient place in the laboratory, one of the steel wire springs furnished you. Determine, as accurately as you can, the length of the spring. Attach to the lower end a 1 or 2 oz. weight. Again measure the spring. Remove the weight. Does the spring return to its original length? Repeat with a 3 or 4 oz. weight.

5. Expansibility and Compressibility.

See Avery, Arts. 43 and 44.

EXERCISE 53. Force from the lungs a little air into the small rubber bag provided you. Place the bag under the receiver of the air-pump and exhaust. What do you observe, and how do you explain?

NOTE.—Ask for assistance the first time you use the air-pump.

EXERCISE 54. Nearly fill a glass tube, having a bulb blown at one end, with water. Invert the tube and put it in a vessel which has been placed on the plate of the air-pump. Cover with a receiver and exhaust the air. What do you observe and how do you explain? Now admit air into the receiver. What do you observe and how do you explain?

EXERCISE 55. Place one arm of a "U" tube through the stopper of a bottle half full of water. Place the other arm into an open bottle. Place both under the receiver of an air-pump, and exhaust. What do you observe? Explain. Now admit the air. Observe and explain.

Exercise 56. Pass a glass tube, drawn to a point at the upper end, through the stopper of a bottle partly filled with water. Force air from the lungs into the tube. On removing the mouth from the tube, what do you observe? Explain.

Exercise 57. Into a "U" tube, furnished you, having a short arm closed and a long arm open, pour a sufficient quantity of mercury to close the bend in the tube. Mark the height at which the mercury stands in each tube by pasting on it small pieces of paper. Now add more mercury to the long arm. How does the length of the column of air change with reference to the column of mercury?

Exercise 58. To the metallic rod (supported on a framework, and having an index attached to one end), which will be furnished you, apply heat from the Bunsen-burner. Note the variation of the index. What is the cause of it?

Exercise 59. Pass a piece of glass tubing through a rubber stopper and insert the stopper into a clean, dry generating flask. Place the other end of the tubing into a tall bottle or cylindrical jar, partly filled with water. Gently heat the flask. What do you observe? Explain.

Exercise 60. In the laboratory will be furnished you a brass ring and ball. Can you pass the ball through the ring? If so, heat the ball in the Bunsen flame for a few moments. Can you now pass it through? If, at first, you were unable to pass it through, heat the ring in the Bunsen flame. Can you now pass it ? Explain in each case.

Why do vessels, containing water, frequently burst, on freezing ?

Explain changes in railroad irons, iron bridges, etc.

6. POROSITY.

See Gage, Elements of Physics, Art. 6.

EXERCISE 61. Fill a test-tube three-fourths full of water and the remaining one fourth with alcohol. Place the finger over the top and invert or shake. Is the tube as nearly full as before? How may you explain?

EXERCISE 62. Measure as accurately as possible, a rectangular piece of wood. Drive several nails into it. Measure again. How do your measurements compare? How may you explain?

7. IMPENETRABILITY.

See Avery, Art. 31.

EXERCISE 63. Pass a glass funnel through a rubber stopper and pass the stopper firmly into the neck of a generating flask. Pour water into the funnel. What do you observe? Explain.

NOTE.—Exercises illustrating this property of matter are very numerous. Devise several and record in your record-books.

8. INDESTRUCTIBILITY.

See Avery, Art. 37; Gage, Art. 10.

EXERCISE 64. Place some splinters of dry pine into a test tube. Wrap a piece of asbestos paper around the upper end of the tube so as to hold the lower end in the flame of a Bunsen burner. Immediately hold a cold, dry piece of porcelain over the mouth of the tube. What do you observe on the porcelain? Now hold a lighted match at the mouth of the tube. What do you observe? Now place a small piece of what remains in the test-tube on a piece of platin-

ium foil, and, with the steel tongs, hold it persistently in the non-luminous flame of the Bunsen burner. Can you entirely burn it?

NOTE.—You may obtain the apparatus above from one of the chemistry pupils.

EXERCISE 65. Place in a test-tube a small piece of copper (about $\frac{1}{4}$ *g.*), and add about a [cm.^{3}] of nitric acid. Hold the tube in one hand for a few minutes, lightly tapping the lower end with a finger of the other hand. Do you observe any change in color? Can you detect any change in quantity?

EXERCISE 66. Pour 1 [cm.^{3}] of lead acetate into a test-tube. Add 1 [cm.^{3}] of hydrochloric acid. What do you observe? Do you notice any change in quantity?

EXERCISE 67. Pour 1 [cm.^{3}] of sulpho-cyanide into a test-tube. Add 1 [cm.^{3}] of ferric chloride. What do you observe. In the above you have changed the appearance and, in fact, changed the nature of the substances, but have you any reason for thinking you have created or destroyed any substance?

EXERCISE 68. Pour 1 [cm.^{3}] of potassium ferro cyanide into a test-tube. Add 1 (cm.^{3}) of ferric chloride.

EXERCISE 69. Prepare a test-tube half full of starch paste (by placing in the tube $\frac{1}{2}$ *g.* of starch. 4 or 5 [cm.^{3}] of water, and boiling in the Bunsen flame). Add a few drops of nitric or hydrochloric acid. Now add one drop of potassium iodide. Or to the starch paste, add a drop of a solution of iodine. What do you observe?

EXERCISE 70. Fasten a piece of candle to the stopper of a dry, clean bottle. Light the candle and insert the

stopper into the bottle. After the candle has gone out, partly fill the bottle with water. Partly fill a similar bottle, in which a candle has not been burned. Now add 10 or 15 ($cm.^3$) of lime water to each. Shake thoroughly. Do you notice any difference in the appearance of the water in the two bottles?

NOTE.—The exercises, given above, show us some of the changes that take place in matter; but only in a general way, that matter is indestructible. This has been shown, conclusively, but the exercises are more delicate than we can perform in our laboratory.

9. INERTIA.

See Avery, Art. 38; Gage, Art. 68.

EXERCISE 71. In the laboratory will be furnished you a support, on which is mounted, vertically, a pedestal and steel spring. Place a calling card or piece of cardboard of similar size upon the pedestal. On the card place a lead ball or similar body. Pull back the spring and allow it to strike the card. What do you observe? Explain.

NOTE 1. This subject will be treated further, under the 'First Law of Motion."

NOTE 2. Copy in your record books and learn the definitions of the Universal Properties of Matter, illustrated by the exercises thus far given.

SOME CHARACTERISTIC PROPERTIES.

NOTE. For the present you may substitute the word "particle" whenever the word molecule occurs in references given.

See Avery, Arts. 19, 21 and 46; Gage, Arts. 22 and 23.

COHESION AND ADHESION.

EXERCISE 72. Suspend from one of the pans of the Sp. Gr. balance, the piece of plate glass furnished you. Place under the glass plate a vessel of water, the surface of which is on a level with the other scale pan. See that the glass is suspended at such a height that when it rests on the surface of the water, the balance beam will be horizontal. Add weights to the second pan until the glass is lifted from the water. How much weight do you need to add? When the plate first breaks from the water, is it dry on the under side, or is there a film of water over it? How may you see adhesion and cohesion here illustrated? Which is the stronger.

EXERCISE 73. Repeat as above, substituting alcohol for the water. Answer the questions given in exercise 72.

EXERCISE 74. Repeat as above, substituting mercury for the alcohol. Answer the questions as above.

I. QUESTIONS.

From Gage, p. 34.

1. Why will not water wet articles that have been greased?

2. Why is it difficult to lift a board out of water?

3. Why does water run down the side of a tumbler when it is inclined, instead of falling vertically? Suggest some method of preventing it.

4. In what does the value of cement, glue and mucilage consist?

5. What enables you to leave a mark with a pencil or crayon?

HARDNESS.

See Avery, Art. 47; Gage, Art. 26; from which copy into your record books "Mohr's Scale of Hardness."

EXERCISE 75. Determine the relative degrees of hardness of the following: Chalk, talc, quartz, corundum, glass, lead, iron, copper, and marble.

TENACITY.

See Avery, Art. 48; Gage, Art. 32.

Exercise 76. Pull and twist a short piece (5 cm. long) of rubber tubing, and also the piece of whalebone previously used. Pull out a steel coil spring. Does it require some effort? Does it break? Why not?

BRITTLENESS.

See Avery, Art. 49; Gage, Art. 29.

EXERCISE 77. Strike with a hammer a small piece of glass resting upon a hard surface. Also a piece of porcelain. Do the same with a piece of rubber tubing or a rubber ball. What are your results?

MALLEABILITY.

See Avery, Art. 50; Gage, Art. 31.

EXERCISE 78. Place a small piece of lead upon a hard surface. Hammer it with light blows on all parts. Can you "spread it out" into a thin piece?

DUCTILITY.

See Avery, Art. 51; Gage, Art. 31.

EXERCISE 79. With one end in each hand, hold a piece of glass tubing in the Bunsen flame. When it is heated to

redness pull the hands apart, moving the glass from the flame at the same time. What do you observe?

EXERCISE 80. File one end of a piece of copper wire until it is reduced in diameter. Now pass the reduced end through a hole in the wire "draw plate" furnished you, in which it fits closely. By means of the plyers, pull the whole piece through the plate. Repeat, using a piece of platinum wire. Are you able to draw them out into finer wires?

CRYSTALLIZATION.

EXERCISE 81. Pour a warm concentrated solution of ammonium chloride or ammonium nitrate upon a clean piece of window glass. Now let the liquid run off, and hold the glass between yourself and the window five or ten minutes. What do you observe?

EXERCISE 82. Obtain a piece of marble and break it, in order to expose a fresh surface. Examine this surface with a hand-glass. How does it differ in appearance from the surface of a piece of lead or brass?

EXERCISE 83. On the first morning on which you discover a heavy frost, examine closely with a hand-glass, a portion of the frosty surface. Describe its appearance. Do the same with flakes of snow.

AMORPHISM.

EXERCISE 84. Examine with a hand-glass, some wheat flour, corn meal, iron and copper filings. Do the particles differ in form and regularity from those previously examined? If so, describe how they differ.

NOTE.—Ask your instructor to show you the different forms in which sulphur may exist.

2. QUESTIONS.

1. What is the smallest measurement of length you have been able to make? Give in both systems.

2. Of area? Give in both systems.

3. Of volume? Give in both systems.

4. Exercises 1–31 illustrate what property of matter? Define it.

6. Discuss the terms, Relative Weights, Relative Densities and Specific Gravities.

7. Give two or more ways of finding the Sp. Gr. of a substance.

5. Exercises 31–48 illustrate what property of matter? Define it.

8. Exercises 48–50 illustrate what property of matter? Define it.

9. Exercises 50–53 illustrate what property of matter? Define it.

10. Exercises 53–61 illustrate what property of matter? Define it.

11. Exercises 61–63 illustrate what property of matter? Define it.

12. Exercise 63 illustrates what property of matter? Define it.

13. Exercises 64–71 illustrate what property of matter? Define it.

14. Exercise 72 illustrates what property of matter? Define it.

15. Review first set of questions.

16. Exercise 75 illustrates what property of matter? Define it.

18. Exercise 77 illustrates what property of matter? Define it.

19. Exercise 78 illustrates what property of matter? Define it.

20. Exercises 79–83 illustrate what property of matter? Define it.

21. Exercise 84 illustrates what property of matter? Define it.

SECTION II.

CONDITIONS OF MATTER.

See Gage, Art. 16; Avery, Arts. 53, 54, 58, 57, 59, and 60.

EXERCISE 85. Place some ice, broken into small pieces, into a test-tube and hold it near to the flame of a Bunsen burner. Study carefully what you see take place until the test-tube is dry. What is the condition of the contents of the tube when you first hold it near the flame? How does it change? In what condition of matter is it after you have held it near the flame for a few minutes? How does it next change? What is the distinction between a gas and a vapor? (See Webster's Unabridged Dictionary).

EXERCISE 86. Sprinkle a few particles of sawdust on the surface of a vessel of water and stir it with a glass rod or a stick. Have you reason to believe that the particles of water move readily about each other?

EXERCISE 87. (At home.) In a darkened room, in which there is a beam of light passing, brush a portion of your wearing apparel, the carpet, or a piece of upholstered furniture. Have you reason to believe that the particles of air move readily about each other?

EXERCISE 88. Cork a bottle partly filled with smoke, place it under the receiver of an air-pump, and exhaust. Have you reason to think that the particles of air which carry the particles of smoke, tend to move away from each other? Air illustrates what condition of matter?

CHAPTER II.

FORCE

AND

ITS ACTION UPON MATTER.

SECTION I.

HEAT AND DYNAMICS.

THE MOLECULE.

THE MOLECULE. See Avery, Art. 5; Gage, Arts. 3, 4, 5, 7, 8 and 9.

FORCE. See Avery, Art. 64; Gage, Arts. 12; Trowbridge, pp. 52–57; Avery, Arts. 102 and 103. Gage, Art. 104 and 105.

MOLECULAR MOTION.

EXERCISE 89. Repeat exercise 59. Why do the bubbles rise from the lower end of the tube? How may you conceive the positions of the molcules of air in the generating flask to change? What seems to be the cause of that change?

EXERCISE 90. Pass a long piece of glass tubing of small bore, through a rubber stopper. Partly fill a generating flask with water and insert the stopper. See that the lower end of the glass tubing is some distance in the water. Now heat the bottom of the flask gently. What do you observe? Have you reason to think there is a change in the molecules

or a change in the distance between the molecules of the substances in the generating flask? What is in the flask beside the water? Have you reason to think that the molecules of this substance change their distances as well as the molecules of water? Repeat, filling the flask full of water. Assuming that the molecules are wholly incapable of moving themselves, what conclusion must we draw? What name do we give to this cause of the change of position of the molecules? What do we say of a molecule or body when its position is changing?

EXERCISE 91. Repeat exercise 60. Ask yourself the question above.

EXERCISE 92. In the laboratory will be furnished you a tin vessel about 10x10x80 cm., nearly filled with water. At one end is a hook while at the other end on either side are supports on which a roller moves freely. To the roller is attached an index about 30 cm. long, which moves before a scale attached to the side of the vessel. There will also be furnished you several rods of different metals. After measuring accurately, attach one end of one of the rods to the hook, letting the other end rest on the roller. Reduce the temperature of the water to $0°$ *C.* and place the index at *o* on the scale. Now raise the temperature of the water to $100°$. Compute from the reading on the scale the actual expansion of the rod. What is the coefficient of expansion of the metal used? Compare your results with reference table. Give the method of determining in full. Repeat with the other rods.

EXERCISE 93. Rub vigorously a metallic button or ball upon a woolen cloth or cushion. Does it feel warmer than at first?

EXERCISE 94. Hammer a piece of wire or a nail upon an anvil. Does it become warmer? See Gage, Art. 102.

EXERCISE 95. Partly fill a test-tube with water. Fill one-third the remaining space with sulphuric acid. Now clasp the tube firmly. Does it become warmer?

NOTE.—Ask an assistant to aid you while performing exercises 96–101.

EXERCISE 96. Place in a test-tube half a [cm^3] of potassium hydroxide. Add a few drops of sulphuric acid. Does the tube become warmer?

EXERCISE 97. Place half a [cm^3] of potassium hydroxide in a test-tube and add a few drops of hydrochloric acid. Does the tube become warmer?

EXERCISE 98. Place in a test tube a few drops of ammonium hydroxide. Add one drop of sulphuric acid. Does the tube become warmer?

EXERCISE 99. Place in a test tube one-half a [cm^3] of ammonium hydroxide. Add a few drops of hydrochloric acid. Does the tube become warmer?

EXERCISE 100. Place in a test tube three or four [$cm.^3$] ammonium hydroxide. Add about the same quantity of acetic acid. Does the tube become warmer? See Gage, Art. 105.

NOTE. For relation between heat and mechanical motion see Dynamics. See Avery, Art. 538; Gage, Art. 104.

Temperature: See Avery, Art. 539; Gage, Arts. 108 and 109.

EXERCISE 101. Pour into a vessel containing water at about 10° C, water at about 80° C. What is the temperature of the mixture?

DIFFUSION OF HEAT.

See Avery, Arts. 602, 603 and 604; Gage, Art. 110.

CONDUCTION OF SOLIDS.

EXERCISE 102. Hold one end of one of the rods used in Exercise 92 in your hand, and the other end in a Bunsen flame or in the flame of an alcohol lamp. Does it soon feel warm? Do the same with a piece of glass tubing. Does it increase in warmth as rapidly as the rod previously used? Repeat, using all the rods used in Exercise 92. Record them in the order of their conductivity.

EXERCISE 103. In the laboratory will be furnished you a metallic ball in which are a number of holes. Place the rods used in Exercise 92 in these holes, supporting the ends. Place a small ball of wax about 3 cm. from the outer end of each rod. Now place a Bunsen burner or a lamp under the metallic ball. Record the rods in the order in which the balls of wax drop off. What is the relative conductivities of the rods?

CONDUCTION IN LIQUIDS.

See Avery, 605; Gage, p. 143.

EXERCISE 104. Place a piece of ice in an eight-inch test tube. Fill it three-fourths full of water. Remove the moisture from the outer surface of the tube and cautiously bring the portion *just below* the surface of the water near to the Bunsen flame. Are you able to boil the water without melting the ice? Is water a good or a poor conductor of heat?

EXERCISE 105. In the laboratory will be furnished you a cylindrical tin vessel, the altitude of which is about 5 cm. and its diameter 10 cm. In the bottom of the vessel is an

opening about 3 cm. in diameter. Pass a 4 in. test tube about half way through a stopper and insert the stopper into the opening in the bottom of the vessel. Place a piece of ice in the bottom of the test tube, and fill the remaining space with ether. Pass a piece of rubber tubing 70 or 80 cm. long, over the mouth of the test tube, and support it in a vertical position. Now nearly fill the vessel with water, and heat it. Are you able to boil the ether without melting the ice?

CONDUCTION OF GASES.

See Avery, Art. 605; Gage, p. 143.

CONVECTION—LIQUIDS.

See Avery, Art. 606; Gage, p. 111.

EXERCISE 106. Fill a generating flask one-half full of water, and add a few particles of fine saw dust. Support the flask on a ring stand, on which is wire gauze or asbestos paper, and heat slowly at first. Watch carefully any movements in the flask you may observe until the water boils, and record.

EXERCISE 107. Repeat, using a test tube, partly filled with ether, lowered into the water in the generating flask. Record. (Use precaution as in Exercise 105.)

CONVECTION—GASES.

See Avery, 606; Gage, 111-12.

EXERCISE 108. In the laboratory will be provided you a long tin box, on which is a cover tightly fitted. At one end of the cover is a support for an Argand chimney, inside of which is a support for a candle. Between these supports are openings through the cover. At the other end of the cover

is a support for an Argand chimney, inside of which is an opening through the cover. Place a lighted candle and the chimneys on the supports for them. After the candle has burned for a few moments, hold a smoking taper over the other chimney. What do you observe? Explain the cause of the movements you see. (Ventilation will be discussed by your teacher.)

THERMOMETRY.

Construction of Thermometers—Air Thermometer.

EXERCISE 109. Pass a piece of glass tubing through a rubber stopper, and insert into a generating flask, as in Exercise 59. Now, invert the flask, placing the end of the tube in a bottle containing water. Cool the air in the flask by breaking up pieces of ice, placing them in a piece of cloth or in a cloth bag, and wrapping the cloth or bag around the flask. When the water ceases to rise in the tube, mark its height by placing a small piece of gummed paper on the tube. Mark on it 0° C. Now, allow the air in the flask to become the temperature of the air in the room. Mark the height of the water as before. Read the Centigrade thermometer that is hanging in the room. Mark the reading on the strip of gummed paper as before. Divide the space between the two points into as many equal parts as there are degrees between 0° C and the reading of the Centigrade thermometer.

Water Thermometer

EXERCISE 110. Insert a piece of glass tubing about 10 cm. long into a rubber stopper, and insert the stopper into a generating flask filled with water. Pack the flask in ice broken in fine pieces. After the flask has been in ice for half an hour, pour water into the tube until it stands above

the stopper. Mark, as in Exercise 109, 0° C. Now, place the flask in water having the temperature of the room. Record as above. Continue to increase the temperature of the water in which the flask is placed, until the water boils, and record on the tube.

EXERCISE 111. (Optional.) Construct a mercurial thermometer.

INSTRUCTIONS.—Provide yourself with a glass tube with a bore not exceeding 1-16 of an inch in diameter, and having a bulb ½ inch in diameter blown at one end. Fill the bulb with mercury. This may be done by expelling the air from the bulb by heating. Expel the air from the mercury as fully as possible by boiling. When the mercury is heated to the boiling point of water, close the upper end by fusing about 5 cm. above the surface of the mercury.

Graduate by comparing with a standard chemical thermometer, at intervals of 10°. Subdivide into equal parts.

To fix the scale, etch with hydrofluoric acid.

EXERCISE 112. To determine the freezing point of water.

INSTRUCTIONS.—Break into small pieces a sufficient quantity of ice to fill a vessel of the capacity of two or three litres. Imbed the bulb of the thermometer sufficiently under the ice to bring the 0° just above the surface. As the ice melts remove the water from the bottom of the vessel. Note the height of the mercury when it becomes stationary. Repeat, using Fahrenheit thermometer.

ABSOLUTE ZERO.—See Avery, Art. 558; Gage, Art. 124.

EXERCISE 113. Determine the boiling point of water.

INSTRUCTIONS.—Provide yourself with a generating flask

of the capacity of one or two litres. Fill it one-half full of water. Pass a C. and a Fahr. thermometer through a cork stopper, through which are several perforations. Allow the stopper to rest on the mouth of the flask. Lower the thermometers until the bulbs are just above the surface of the water. Now heat the water and continue the boiling until the mercury in the thermometers becomes stationery. Note the readings.

NOTE.—For method of reducing from C. scale to Fahr., and vice-versa, see Avery, Art. 546; Gage, Art. 121.

EXERCISE 114. Determine the boiling point of ether. (Ask the aid of an assistant.)

INSTRUCTIONS.—Place the generating flask arranged as above, on a water bath. Place in the flask ether instead of water. Proceed as above. (Use precaution as in Exercise 105.)

EXERCISE 115. Determine the boiling point of alcohol. Proceed as above, substituting alcohol for the ether.

EXERCISE 116. Determine if variation of pressure on the surface of a liquid will vary the temperature at which it boils.

INSTRUCTIONS. Fill the flask, used above, half full of water. Heat until it boils. Now remove the heat, cork tightly and invert. Pour cold water on the flask. Does the water now boil? Explain. See Avery, Art. 570; Gage, page 160.

LAWS OF FUSION AND BOILING.

See Avery, Arts. 567, 569, 573, 574 and 575; Gage, pages 161 and 162.

DISTILLATION.

EXERCISE 117. Fill a generating flask nearly full of water, and lead a delivery tube into a second flask or bottle that is partly immersed in a vessel of cold water. Heat the water in the first flask until it contains about one-half as much water as at first. Does the second flask contain water? Where did it come from? How could the water escape from the first flask? What conditions of matter are illustrated?

EXERCISE 118. Place in a generating flask one part of alcohol to three parts of water. Pour a few [$cm.^3$] of it into an evaporating dish, and try to ignite it. Now connect the flask with a Liebig condenser. Heat the contents of the flask as much as you can without boiling. When the contents of the flask have decreased about one-half, remove the heat and try to ignite a few [cm^3] of the distillate placed in an evaporating dish. If you are unable to do so, place the distillate in the first flask and repeat as above.

Continue until the distillate will ignite.

ARTIFICIAL COLD.

EXERCISE 119. Moisten a piece of wood and place on it a beaker containing carbon bisulphide. Blow through a glass tube into the beaker until it is empty. What are your observations?

EXERCISE 120. Repeat, using ether instead of carbon bisulphide.

EXERCISE 121. Fill the palm of the hand with ether and hold it a few minutes. What is the sensation?

EXERCISE 122. Repeat, using alcohol instead of ether.

LATENT AND SPECIFIC HEAT.

Read Avery, Arts. 579–601, inclusive.

Gage, Arts 131–143, inclusive.

EXERCISE 123. In the vessel furnished you, place water and heat until it boils. Now place in the boiling water a second vessel containing 500 grams of ice, and at the same time another vessel containing 500 grams of water at 0 C. Place a C. thermometer in each of the vessels placed in the boiling water. What is the difference in the readings of the thermometers when the ice is nearly all melted?

EXERCISE 124. Place 500 grams of water at 0° C. in a vessel and note the time it takes to raise the temperature to 100° C. Also, continue boiling until all the water has disappeared. What is the ratio of the times required?

EXERCISE 125. In the laboratory will be furnished you an iron ball about the size of a 250 [cm^3] generating flask. Fill the flask with water and place it on a ring stand. Place the iron ball on a second stand. Heat the iron until you are unable to hold your finger on it and note the time required. Do the same with the generating flask, and note the time required. Which time is the shorter? Which has the greater Specific Heat.

EXERCISE 126. Heat during equal periods of time, an iron, a lead, and a brass ball, all being of nearly equal size. Now, drop them on a cake of paraffine or wax. Note the relative depths to which they sink into the paraffine or wax during a given length of time. What are their relative Specific Heats?

NOTE.—For exercises in Radiant Heat, see Radiant Energy.

3. QUESTIONS.

1. Define Molecule.

2. Give several ways in which molecular motion appears.

3. Read and discuss fully Exercises 89, 90 and 91.

4. By what method is increased molecular motion produced in Exercise 93 and 94? What do we call the sensation produced by increased molecular motion?

5. How is heat produced in Exercises 98, 99, and 100?

6. Define Temperature.

7. Define Diffusion.

8. Name and define the methods of diffusion of heat we have studied.

9. Read and explain Exercises 101–109.

10. Explain the principle on which the thermometers in 109–112 are constructed.

11. Describe the different methods of determining the boiling and the freezing points of water.

12. Explain the construction of the scales on the C. and Fahr. thermometers and methods of determining corresponding readings.

13. What are the advantages in using mercury in the construction of thermometers?

14. Define Absolute Zero and explain how it is determined.

15. Give the laws of boiling and fusion.

16. Explain the processes and principle of fractional distillation.

17. Define Latent Heat.

18. What is the Latent Heat of water and how is it determined ?

19. What is the latent heat of Steam and how is it determined ?

20. Define Specific Heat, and and give method of determining.

DYNAMICS OF SOLIDS.

See Avery, Arts. 63, 64, 65, 70-98; Gage, Arts. 65-57.

Your teacher will discuss the following subjects:

Dynamics,
Force,
Elements of Force,
Measurement of Force,
Momentum,
Laws of Motion,
Composition of Forces,
Resultant Motion,
Graphic Representation of Forces,
Parallelogram of Forces,
Determination of the Value of a Resultant, (*a*) mathematically, (*b*) graphically.
Composition of more than two Forces,
Parallelopiped of Forces,
Resolution of Forces,
The example of the Sailing Vessel.

GRAVITATION.—See Avery, Arts. 98-118; Gage, Arts. 68-88.

EXERCISE 127. Place several balls of nearly equal volume and of different material, as wood, iron, lead, etc., on the table and strike them as nearly equal blows as possible. What are the relative distances which they roll?

Repeat, endeavoring to strike them such blows that they will all roll a given distance. Which requires the heaviest blow? Which the lightest?

EXERCISE 128. In the laboratory will be furnished you a large wooden and a large iron ball of about equal volumes. Roll the wooden ball on the floor in such a manner that it will strike a block of wood (about a decimeter square) that you have placed about three meters distant. Note the distance to which the block is carried by the blow.

Repeat, having replaced the block, using the iron ball, rolling it as nearly as possible with the same velocity. Note as above. Which moves the block further? Which has the greater momentum when it strikes the block? Which requires the greater effort to produce a given velocity—i. e., to which do you apply the greater force?

EXERCISE 129. Place on the floor a smooth block of wood or a board. Let the wooden ball fall upon it from a height of half a metre. Repeat with the iron ball. Which produces the larger dent in the board or block? Which strikes the block with the greater momentum? Which ball has the greater mass? Is the force causing the fall, in each case, the same?

EXERCISE 130. In the laboratory is a frame work on which is mounted a vertical brass rod. About this brass rod are brass hoops, firmly attached to the lower end and sliding on the rod at the upper end. At the upper end of the rod is a handle, by means of which the rod is rotated. How do the hoops change position? What is the cause? What is the First Law of Motion?

EXERCISE 131. A spherical glass vessel containing a few ounces of mercury will be furnished you. To the vessel is attached a cord. Cause the vessel to rotate rapidly by twisting the cord. What position and form does the mercury take? Explain.

EXERCISE 132. Apparatus similar to that illustrated in Avery, Art. 83, will be furnished you. Verify the value of the resultant as determined by the graphical method previously shown you. Or, what is better, construct apparatus out of cords and pulleys fastened to the blackboard in the laboratory.

INSTRUCTIONS.—Tie together the ends of three pieces of strong cord. Pass a cord over each of two pulleys attached to the blackboard, so that when weights are attached to the cords the pulleys may move freely. Attach weights to the ends of the cords, so proportioned that the apparatus is in a statical condition. Construct a resultant on the board. Compare the resultant determined on the board with that determined with the weights.

EXERCISE 133. By means of the "Force and Reflection" apparatus furnished you, i. e., substituting dynamometers for two of the weights in the exercise above, determine the value of the resultant as in the exercise above.

EXERCISE 134. With the apparatus used above repeat, having the components acting from a variety of directions.

EXERCISE 135. With apparatus used above, repeat, having the resultant acting not in the same plane as the components.

EXERCISE 136. Make diagrams illustrating apparatus used in exercises 127-137, if you have not done so in connection with each exercise as performed.

EXERCISE 137. With the apparatus used above determine the law of reflected motion.

INSTRUCTIONS.—Place the reflection block on the base board of the apparatus, so that the face of the block shall

be perpendicular to the line passing through the zero of the scale graduated on the circumference of the base board. By means of the spring hammer attached at various points on the scale, cause the ball furnished you to strike the center of the reflection block. Compare the angles formed by the paths of the ball, and the line perpendicular to the reflection block. Make a diagram. See Avery, Art. 97.

EXERCISE 138. Suspend one of the dynamometers used above, from a convenient place in the laboratory. Slide the three bands (to which are attached hooks) furnished you, upon a meter stick, having the hook on the middle band turned in the opposite direction from that of the other two hooks. Attach the middle hook to the hook of the dynamometer. Attach weights to the lower hooks and move the bands until the meter stick is in a statical condition. How does the sum of the weights compare with the reading on the dynamometer? Make allowance for the weight of the stick. Vary the weights by making different combinations. Compare as above.

EXERCISE 139. On a large vessel of water, e. g., the pneumatic trough, float the two tin dishes used in determining the latent heat of water. Fasten together corresponding corners by means of a rubber band about 30 cm. long. Stretch the band by pulling the dishes apart. Now release them at the same time. Note as carefully as you can the relative velocities with which they move toward each other. Now place a 100 gram weight in the center of each dish, and repeat. Note as above. Do they move as rapidly as before? Repeat, placing 200 grams in each dish, and note as above Repeat, placing 100 grams in one dish, and

nothing in the other. Note velocity. Repeat, placing 200 grams in one dish, and nothing in the other. What are the relative velocities with which they move towards each other? Repeat, placing 300 grams in one dish, and nothing in the other. Note as above.

What is the third law of motion?

NOTE.—In the following exercises in Dynamics, there are frequent applications. Three Laws of Motion. Endeavor to recognize them as they occur.

EXERCISE 140. Slowly bring a large nail or piece of soft iron near to the end of a large bar magnet, or several smaller ones with like ends placed together. Do you find that the increase of the pull of the magnet as you approach is more rapid than the decrease of distance? Repeat several times if you cannot satisfy yourself at first. Verify the law by means of a spring balance and strong magnet.

Now substitute for the magnet a strong electro-magnet, supported in a vertical position. Repeat with a soft iron rod, as in first part of the exercise. Do you obtain similar results? Now hold the rod a short distance from the electro-magnet, and drop so that it will fall into the magnet. Repeat several times. What are your observations?

4. QUESTIONS.

See Avery, Art. 106.

1. How far below the surface of the earth will a 5 kilogram ball weigh but 2 kilograms?

2. Find the weight of a body 5,000 kilometres from the center of the earth that at the surface weighs 275 kilograms?

3. At the surface of the earth a body weighs 450 kilo-

grams. What will it weigh 10,000 kilometres above the surface of the earth?

4. How far above the surface of the earth will a kilogram weigh but a hektogram?

5. What is the difference in the weights of a 100 kilogram ball 5,000 kilometres below the surface of the earth, and 5,000 kilometres above the surface of the earth?

6. How far below the surface of the earth will a kilogram weight become a hektogram weight?

7. How far above the earth must 1,000 kilograms be placed to weigh 100 kilograms?

8. Two bodies attract each other with a certain force when they are 100 kilometers apart. How many times will the attraction be increased when they are 50 kilometers apart?

9. When the distance between two bodies is doubled, how does it affect the attractive force?

10. When the attractive force is doubled, how must the distance between the two bodies have changed?

11. What is the "Law of Weight?"

12. Will a body weigh more or less at the poles of the earth than at the equator? Why?

13. Will the difference, if any, in weight at the equator and at the poles of the earth, be the same if measured with spring scales as if measured with the balance?

14. Will the weight of a given body be the same at all points on the equator, if measured with spring scales? If measured with balance?

15. Explain "Varies directly," "Varies inversely," "As squares," etc.

CENTER OF GRAVITY.

See Avery, Arts. 107-117; Gage, pages 96-100.

EXERCISE 141. Balance a cubical piece of wood or other substance upon one corner.

INSTRUCTIONS.—Hold the cube on one of its corners on the corner of the table. Wind a stiff piece of wire about the cube, having one end projecting several centimetres under the table. Attach a weight to this end of the wire so that it will hang directly under the corner of the cube. Explain.

EXERCISE 142. Suspend a piece of board successively from two or more of its corners, and draw lines across it in the direction of the string by which the board is suspended. Now suspend the board by attaching at the intersection of the lines. Does the board maintain a horizontal position, or nearly so?

KINDS OF EQUILIBRIUM.

See Avery, Arts. 110-111.

EXERCISE 143. Illustrate in the laboratory the three kinds of equilibrium, and describe.

CURVILINEAR MOTION.

See Gage, pages 101-102; Avery, Article 77.

EXERCISE 144. Attach a string about 30 cm. long to a small ball, and cause the ball to revolve about the finger. In how many directions does the ball move while revolving? Is it constantly changing its direction? If so, why? With the end of the string in one hand, and the ball in the other, hold in a horizontal position. Now, let go of the ball. Make a diagram, showing the path in which the ball moves. Is the ball continually changing its direction? If so, why?

Make a diagram resolving the force, acting successively at several points, into its components. Explain in full.

EXERCISE 145. In the laboratory will be furnished you a frame from which are suspended six hardwood polished balls. Designate them, beginning at the left as A, B, C, D, E and F. Place C, D, E and F to the rear of the scale. Now remove A to some distance along the scale, and release. How does it change its motion on striking B? How does B change? Now, when A and B come to rest, remove B and release as you did A. What is the effect? Repeat, placing A, B and C in front of the scale. Describe the motion of the three balls.

EXERCISE 146. Repeat, increasing the number, one each time, until you have used all the balls. Describe the motion of the balls in each case, and explain why they thus move.

Repeat, using two or more lead balls. Do you get the same results? Why?

Falling Bodies: See Avery, Articles 118-120.

EXERCISE 147. Ask one of your classmates to drop from the top story of the school building, simultaneously, the large wooden and the small metallic balls furnished you. Do they strike the ground at very nearly or quite the same time?

EXERCISE 148. With the aid of your instructor, exhaust the air from the guinea and feather tube furnished you. By holding the tube in a vertical position, note as carefully as possible the relative times required by the falling of the two bodies. Explain the cause of the results obtained in the last two exercises.

EXERCISE 149. (Galileo's Device). Determine, with the help of an assistant, the kind of motion produced by the action of gravity.

INSTRUCTIONS.—In the laboratory is arranged an inclined plane in the form of a grooved piece of wood 28 feet long. The piece of wood is so adjusted by means of cords and pulleys, that it can be inclined at different angles. Sliding on the piece of wood are bands of metal, connected with an electric current, in which is an electric bell, and so adjusted that when a metallic ball is rolling down the groove and comes in contact with a metallic band, the circuit is closed and the bell rings. Also in the laboratory is a second's pendulum.

Adjust the piece of wood so as to form an angle of 10° with the table over which it is supported. Now, allow a metallic ball to roll down the groove, and so adjust the metallic bands that the bell will ring at the end of each second. Measure the distance passed over by the ball during each second of time. Repeat, at least, six times, and take as your result the average.

Now, repeat, adjusting the piece of wood successively at angles of 15°, 20°, 25° and 30° with the table, in each case making six trials, and taking the average.

How do the ratios of the distances passed over in succeeding seconds compare? Tabulate your results. Repeat, giving the ball a little push, (or an initial velocity.) How does this affect the ratio called for above?

EXERCISE 150. Determine, with the help of an assistant, the ratio asked for above, by means of Atwood's Machine.

INSTRUCTIONS.—Place the machine on the stone pier in the laboratory. Place one of the weights, attached to the silk thread passing over the pulley at the top of the column, upon the electro-magnet at the base of the column. Place the counter weight on the weight attached to the other end of the thread. Place the bob of the second's pendulum, which is mounted upon the base of the machine, in contact with the electro-magnet. Now break the circuit and note the spaces moved by the upper weight during succeeding seconds, or beats of the pendulum. How do the ratios compare with those obtained in the previous exercise? Repeat several times and take the average. Repeat several times, using different counter weights.

EXERCISE 151. To determine the velocity of the descending weight on Atwood's machine, at the end of any second, arrange the apparatus as above and set the ring on the column so that it will remove the counter-weight at the end of first second. How far does the weight move during the second second? Does it move the same distance during the third second?

EXERCISE 152. (*a*) To determine approximately the distance passed over by a freely falling body during the first second of its fall.

(*b*) To determine the same for the first two seconds of its fall.

NOTE. With the assistance of your instructor, you will be able to perform exercise 152 by means of the apparatus furnished you in the "well" of the stairway of the "main building."

TABLE

FOR RESULTS FROM EXERCISES UNDER FALLING BODIES.

No. of Units of Time. Seconds.	Space Fallen During Each Unit.	Velocity at the End of Each Unit.	Increase of Velocity Each Unit.	Total Distance Passed Over.
1	....	....	....	....
2	....	....	....	....
3	....	....	....	....
4	....	....	....	....
Etc. t.	In terms of t.	In terms of t.	In terms of t.	In terms of t.

The velocity of a freely falling body at the end of the first second or g =

The distance moved by a freely falling body during the first second, or $\frac{1}{2}g$ =

FORMULAS FOR FALLING BODIES.

Letting $\frac{1}{2}g$ represent the space passed during the first second, t the unit of time, v the velocity at the end of any second, s the space fallen during each second, and S the total space passed, find the values of v, s and S in terms of g and t.

5. QUESTIONS.

1. Give the formulas for falling bodies.
2. Which values, in the table of results under falling bodies, are obtained by experiment and which are deduced?
3. What is the effect of an initial velocity upon a falling body? Give the formula.
4. How many meters will a body fall during the first one and a half seconds of its fall?
5. How many meters will a body fall during the third second of its fall?

6. A stone, falling freely, reaches the ground in seven seconds. How far did it fall?

7. A body projected vertically upwards rises 44.6 meters. What was its initial velocity?

8. A body falls for several seconds; during one it passes over 163.3 meters. Which one is it?

9. In Atwood's machine, if the weights carried by the thread are 25 grams each, the friction equivalent to a weight of 10 grams, when the rider or counter weight is in position, what will be its gain in velocity per second?

10. A body was 5 seconds rolling down an inclined plane and passed over 2 meters during the first second. Give (*a*) the entire space passed over, (*b*) the final velocity.

PROJECTILES.

See Avery, Arts. 133-136; Gage, Art. 81.

EXERCISE 153. Place a small wooden or metallic ball on the table about a metre from the end. Hit it sufficiently to cause it to roll off the end of the table. Sketch as accurately as you can, on co-ordinate paper, the path of the ball while moving from the table to the floor.

EXERCISE 154. In the laboratory will be furnished you a vessel containing a lateral opening. Support this about two meters above the floor, and arrange rubber tubing connected with the hydrant, so that you can fill the vessel and keep it so. Now remove the cover from the lateral opening, having arranged vessels to catch the water of the projecting stream. Measure the horizontal distance of the stream from the orifice or opening at successively 1, 2, 3, etc., decimeters below the orifice until you

reach the floor. Record your measurements, and construct on co-ordinate paper the curve formed by the stream of water.

At what point does a ball shot horizontally from a gun begin to fall? When will it reach the ground if the gun is 4.9 meters above the ground? How far will it be from the gun when it reaches the ground, if the gun gave it a uniform horizontal velocity of 30 meters per second?

THE PENDULUM.

See Avery, Art. 137, page 75; Gage, page 111.

EXERCISE 155. Suspend from the ceiling of the laboratory four balls of the same volume and mass; designate them as A, B, C and D. Suspend A and B by strings 99.3 mm. long, C by a string ¼ as long, D by a string $^1/_9$ as long as A. Also suspend from the same height a lath or similar piece of wood.

(*a*) Cause A and B to vibrate by moving them equal distances from the vertical. What do you observe?

(*b*) Cause them to vibrate by moving them unequal distances from the vertical. (In no case should the distance moved be over 7 or 8 degrees from the vertical.) What do you observe?

(*c*) Cause A and C to vibrate by moving them the same angular distance from the vertical. What do you observe?

(*d*) Give A and C different impulses by moving them to different angular distances. What do you observe?

(*e*) Repeat as above with A and D. What do you observe?

(*f*) Make a diagram illustrating the resolution of forces

acting on the vibrating pendulum. Make diagrams of the cycloidal arc, and of the compensating pendulum.

EXERCISE 156. Cause the lath and A to vibrate. Shorten A until it vibrates in the same time as the lath. Measure on the lath, from the upper end, a distance equal to the length of the string A. Bore a hole at this point. Place a small steel rod or wire in this hole, and cause the lath to vibrate on the rod or wire. How does the time compare with that of the previous vibration? See Gage, Arts. 82-83.

EXERCISE 157. Attach a string to the end of the lath and suspend the lath by it.

(*a*) Strike the upper end of the lath. What motions do you observe with reference to different parts of the lath?

(*b*) Strike the lower end of the lath. Observe as above.

(*c*) Strike it opposite the hole you have made. Observe as above.

ENERGY.

Define:—

Work, Energy; The units used in the measurement of forces, as: Gravity Unit, Absolute Unit, Dyne; Elements of Work-measure; Units of work; Foot-pound, Kilogram-metre; The Erg, The C. G. S. unit, as: The Gravity unit in Ergs = ? A Foot-pound in Ergs = ? Horse-power = ? Determine the relation of Velocity to Energy, *i. e.* given V to find S.

See Avery, Arts. 156 and 157.

Define Physics. See Avery, Art. 12.

6. QUESTIONS.

1. How many horse-power in an engine that will raise 8,250 lbs. 176 ft. in 4 seconds?

2. A ball weighing 85.22 kg is rolled with a velocity of 30 meters per second. How much energy has it?

3. A mass of 250 grams is moving with a velocity of 20 cm. a second; through what distance must a force of 60 dynes work in order to stop the motion?

4. A force of 72 dynes acts on a mass of 900 grams through 2 meters; what velocity has been produced?

5. A certain force pushes a mass of 200 kilograms up a smooth inclined plane rising one inch through 3 meters, the mass then goes on for half a meter more before it begins to return; find the force employed, supposing $g = 9.80$.

MACHINES.

See Avery, pages 87–113; Gage, Arts. 100 and 101.

EXERCISE 158. In the laboratory will be furnished you a frame-work on which is mounted a standard. On this standard is mounted, by means of a movable rod, a wooden bar in which is a double row of holes.

(*a*) Support the bar at its center and attach equal weights at the extremities. Does the bar remain in a horizontal position? Designating one weight by W, the other by P, the support by F, the distance from W to F by W F, and the distance from P to F by P F, find the product of P × P F and W × W F. Repeat several times, increasing P and W, and find product as above.

(*b*) Change the point of support of the bar, and repeat several times, as above, and compare products.

(*c*) Change the point of support to one end of the bar. By means of the sliding pulley on the upper portion of the frame-work, attach a weight to the other end of the bar, so

that it will act in opposition to gravity. Now, balance the bar by placing a weight at some intermediate point on it. Compare products as above.

(*d*) Exchange points of attachment of the upward and downward weights. Compare as above.

(*e*) Repeat case (*a*), using two more weights on each arm. Compare as above.

(*f*) Repeat one or more of the cases above, using a bent bar, having the weights acting at an angle with each other. What is the true arm of a bent bar or lever? Determine from this exercise the "Law of Levers."

EXERCISE 159. Determine the accuracy of the Sp. Gr. balance in the laboratory.

INSTRUCTIONS—. Place some solid substance first in one pan and weigh it, and then in the other and weigh. Find the square root of the product of the two weights. Compare your result with half the sum of the two weights.

EXERCISE 160. Obtain the accurate weight of a substance by means of a false balance.

INSTRUCTIONS.—Place the article in one pan and some finely divided substance, as sand or fine shot, in the other, until the beam is horizontal. Remove the article and replace with weights until the scales balance.

EXERCISE 161. Construct a compound lever.

INSTRUCTIONS.—At the lower end of the bracket, attached to one of the walls of the laboratory, construct a lever of the second class. At the upper end of the bracket, construct a lever of the first class. Make the power of the lever of the second class the weight of the lever of the first class. Construct at the center of the bracket a lever of the sec-

ond class. Make the power of the second lever constructed, the weight of the third lever. Determine the statical law of such a construction. What are some of the practical applications of the compound lever?

See Avery, Art. 178.

WHEEL AND AXLE.

EXERCISE 162. Determine the relation between the weight attached to the wheel and that attached to the axle.

INSTRUCTIONS.—In the laboratory is a wooden cylinder mounted upon a steel rod, the ends of which rest on smooth "bearings." At opposite points on the cylinder are wooden pegs.

(*a.*) Wind a string about the iron rod, and attach a weight to it. Wind a string about the cylinder in the opposite direction, and attach a weight sufficient to balance the system. Are the weights the same? Why? Compare with levers and explain.

(*b.*) Repeat, attaching a weight to the end of one of the wooden pegs instead of the cylinder. Compare with levers as above. What is the advantage of the wheel and axle?

EXERCISE 163. Connect two wheels or pulleys of different diameters by means of a belt or cord. Find the ratio of the number of revolutions of the two wheels during one revolution or the belt. Are the directions in which the wheels rotate the same, or opposite?

See Avery, Arts. 179-192.

EXERCISE 164. By means of the apparatus furnished you, verify the "Law of Wheel-Work." See Avery, Arts. 185-186. What are the names of the wheels and their parts?

THE PULLEY AND INCLINED PLANE.

See Avery, Arts. 192-204; Gage, Art. 101.

EXERCISE 165. (*a.*) Attach a pulley to the support provided for it in the laboratory. Pass a cord over it, and attach a dynamometer to each end. To one of the dynamometers attach a weight, and hold the hook of the other in the hand, thus preserving the statical condition of the machine. Note the readings of the dynamometers.

(*b.*) Attach one end of a cord to the support, passing the cord under a pulley to which is attached a weight. Continue as above.

(*c.*) Repeat, increasing the number of cords until the pulleys are all used. What is the "Law of the Pulley?" See Avery, Art. 196.

INCLINED PLANE.

EXERCISE 166. With the apparatus furnished you, called the "Inclined Plane," find the weight required to balance the weight resting on the plane:

1. When acting vertically and parallel with the plane.
2. When acting vertically and parallel with the base of the plane.
3. When acting vertically and neither parallel with the plane or base, but at an angle one-half that formed by the plane and its base.

Determine by graphic method. Record your diagrams. See Avery, Arts. 199-204. Gage, page 137.

THE WEDGE AND THE SCREW.

See Avery, Arts. 205-208.

EXERCISE 167. In the laboratory will be provided you a

screw moving in a frame work. Measure the length of the screw and count the number of threads. Determine the pitch of the screw. Also, measure the length of the pin passing through the head. Compute the weight that may be raised by the screw when a force of 5 hgs. acts upon each of the ends of the pin. Verify by experiment. Does the principle of the "Wedge" differ from that of the Screw? If so, how?

FRICTION.

See Avery, Arts. 212-213; exercise on p. 113.

EXERCISE 168. With the apparatus furnished you, verify the "Eight Facts Concerning Friction" given in Avery, Art. 214. Tabulate your results.

7. QUESTIONS.

1. State some of the uses of machines.
2. Define the classes of levers, and illustrate by diagram.
3. Illustrate by diagram a system of pulleys by means of which 5 hgs. will support 25 hgs.
4. Illustrate by diagram a system by means of which a weight of 3 hgs. will support a weight of 27 hgs.
5. Illustrate by diagram the force, parallel to the plane, necessary to maintain a cask weighing 100 hgs. in a statical condition on a plane at an angle of 20°.

DYNAMICS OF LIQUIDS.

See Avery, Arts. 215-222; Gage, Arts. 52-53.

EXERCISE 169. In the laboratory will be furnished you a piece of apparatus called the "Hydrostatic Bellows." Com-

pute the area of the upper surface of the bellows; also the area of a cross section, and the volume, of the vertical tube. Place about 50 hg. weights on the bellows. Now pour water into the tube until it is full. Have you raised the weights? Increase the weights until the water overflows the tube. Compare the ratio between the area of a cross section of the tube and the area of the upper surface of the bellows, with the ratio between the weight of the water in the tube and the weights on the bellows. Make a diagram, "drawn to a scale," of the hydrostatic bellows.

Give Pascal's "Experiment."

Give Pascal's Law.

Write a short sketch of the life and works of Pascal.

THE HYDROSTATIC PRESS.

See Avery, Art. 223; Gage, Art. 54.

EXERCISE 170. Construct a diagram, "drawn to a scale," of a Hydrostatic Press, and compute from your diagram the efficiency of such a press.

PASCAL'S VASES.

See Avery, Art. 225; Gage, page 67.

EXERCISE 171. With the apparatus furnished you, determine the pressure on the bottom of each vessel when filled with water. Compute the volume of water held by each of the vases. What is the rule for finding the downward pressure on a horizontal surface.

See Avery, page 124.

EXERCISE 172. By means of the cylindrical vessel, with a movable base, furnished you, and a large vessel of water,

determine the rule for upward pressure on a horizontal surface.

See Avery, Art. 228.

EXERCISE 173. Make a diagram illustrating and explaining the "Hydrostatic Paradox."

See Avery, Art. 229.

EXERCISE 174. In the laboratory will be furnished you a "U" tube with one short arm, and also a second "U" tube similar to the first but having the opening of the short arm, lateral. Place enough mercury in the first to nearly fill the short arm. Gradually lower it into water until the surface nearly reaches the top of the long arm. Mark this point and the point to which the mercury rises in the long arm. Repeat with the second "U" tube. How far is the mercury moved by the water in each case?

8. QUESTIONS.

1. A cylindrical vessel having a base of 1 sq. cm. is filled with water to the depth of two meters. What pressure is exerted on the base?

2. What will be the upward pressure upon a horizontal plate one decimeter square at a depth of 100 decimeters?

3. A conical vessel has a base with an area of 200 [cm^2.] Its altitude is 50 cm., and it is filled with water. What is the pressure on the bottom?

4. The lever of a hydrostatic press is 2 meters long, the piston-rod being 2 dm. from the fulcrum. The area of the tube is 2 [cm^2.] that of the cylinder is 400 [cm^2.] Find a weight that may be raised by a power of 50 kgs.

5. What will be the pressure on a dam in 10 meters of water, the dam being 5 meters long?

EQUILIBRIUM.

See Avery, 232–234.

EXERCISE 175. Arrange the vessel with the lateral opening so that the opening may be connected with a tube bent at right angles and the vertical portion of sufficient length to reach the top of the vessel.

(*a.*) Fill the vessel with water and note the height to which it rises in the tube.

(*b.*) Repeat, with the tubes bent in various forms.

(*c.*) Connect the lateral opening with the mouth of a bottle from which the bottom has been removed. Repeat as above.

CAPILLARITY.

See Avery, Arts. 235 and 236; Gage, Art. 34.

EXERCISE 176. In the laboratory will be furnished you a half dozen glass tubes, with bores of different diameters. Beginning with the smallest, measure the diameter of the bore, then place it vertically in a vessel of water. Measure the height to which the water rises in the tube above the surface of the water in the vessel. Repeat in like manner with each of the tubes. Thoroughly cleanse all before using.

Repeat, using mercury.

What are the laws of Capillarity?

ARCHIMEDES PRINCIPLE

See Avery, Arts. 237-240; Gage, pages 76-79.

EXERCISE 177. In the laboratory will be furnished you a Sp. Gr. balance, and a brass cup in which is a closely fitting brass cylinder. Attach the cup to the hook under the scale pan, and the cylinder to the base of the cup. Balance the scales. Now, fill the cup with water, and place

a vessel of water so as to immerse the cylinder just to its upper surface, when the scale beam is horizontal. Does the scale beam remain horizontal? How does the volume of water displaced compare with the volume in the cup? How does the buoyant effect compare with the weight of the water in the cup?

Why do some bodies float? Why do others sink? When will a body float, and when sink? How deep does a floating body sink into a liquid? Where have we used the principle observed above?

HYDROKINETICS.

Read Avery, Arts. 254–267.

DYNAMICS OF GASES, OR PNEUMATICS.

See Avery, Arts. 268-301; Gage, Arts. 43-62.

EXERCISE 178. Invert an eight inch test tube, a tumbler or similar vessel in a dish of water, and raise it nearly to the surface. What do you observe? Why does the water remain in the inverted vessel?

Repeat with a piece of glass tubing, (Argand lamp chimney,) having a rubber bottom. Does the rubber change form? If so, why?

EXERCISE 179. Fill a test tube or tumbler with water. Press a piece of paper or card firmly on the top, holding it while inverting. When inverted, does the paper continue on the tumbler? If so, why?

EXERCISE 180. In the laboratory will be furnished you two hemispherical brass cups, with ground edges. Place them firmly together, and exhaust the air. Ask a classmate to help you pull them apart. Again exhaust the air,

and determine the force necessary to pull them apart by suspending by one handle and attaching weights to the large dynamometer that has been attached to the other handle. Compute the pressure that held the cups together, and compare with the experimental results you obtained.

EXERCISE 181. Place a rubber bag, containing a little air, under the receiver of the air pump, and exhaust. Explain the cause of the change of volume of air in the bag.

EXERCISE 182. Insert a tube, with a bulb at one end nearly filled with water, in a bottle containing a little water. Place the bottle under the receiver of the air pump, and exhaust. Explain the cause of the change of volume of air in the bulb.

EXERCISE 183. Pass one arm of a "U" tube through the stopper of a bottle nearly filled with water and the other arm into an empty bottle. Place both under the receiver of an air pump, and exhaust. Explain why the water passes from the stoppered bottle into the other. Admit the air. Explain why the water flows back into the first bottle.

EXERCISE 184. Repeat Exercise 57. What is the law expressing the relation between volume and pressure? Continue Exercise 57 by adding more mercury. Does the law still hold true? After whom was this law named?

EXERCISE 185. Exhaust the air from the brass globe furnished you and weigh it. Now admit the air and weigh again. Compute the volume of the globe and determine the weight of the air it contained. Did the manometer on the air pump indicate total exhaustion? If not, take the reading of the manometer and compute the degree of exhaustion. (See Avery, Art. 289.) Make allowance accordingly

in determining the weight of the air in the globe. Compare your results with table of references.

EXERCISE 186. (Torricelli's Experiment.) Fill a glass tube, 80 cm. long, closed at one end, with mercury. Invert in a vessel of mercury. Measure the distance between the surface of mercury in the tube and that in the vessel outside the tube. Read the barometer and compare. Repeat, using a tube with a bore of a different size. Compare with results above. Why does the mercury remain in the tube? Why are the results the same whatever the size of the tube, if allowance be made for capillary action? Would capillary action increase or decrease the length of the column of mercury? Measure the volume of mercury in either of the tubes and compute an atmosphere. (See Avery, Art. 227.) Give Pascal's Experiment and results obtained.

EXERCISE 187. Make a diagram of Fortin's Barometer. See Stuart & Gee, page 205, or Deschanel, page 147.

Explain the principle involved in the construction of the barometer. Make a diagram of the Aneroid Barometer, and explain the action. See Avery, page 161, or Deschanel, page 157.

EXERCISE 188. In the laboratory will be furnished you a small air pump. Take it apart, and examine until you thoroughly understand it. Then put it together and test the accuracy of your work by making an exhaustion with it. Make an accurate diagram of an air pump, giving especial attention to the valves. See Avery, page 169; see Gage, page 54.

EXERCISE 189. Exhaust the air from the guinea and

feather tube. Place the stop-cock in a vessel of water, and open. Explain.

EXERCISE 190. Cut out a circular piece of leather and soak it in water. Attach a string to the center. Firmly press the leather against a smooth, flat surface. Pull on the string. What is the result? Explain.

EXERCISE 191. Place a hand glass upon the plate of the air pump. Place your hand over it, and ask some one to partly exhaust. Do you believe air has weight? If you are not fully convinced, ask for further exhaustion.

EXERCISE 192. Tie a piece of sheet rubber over the opening in the hand glass and exhaust.

EXERCISE 193. Compress air by means of the condenser furnished you, and tie a piece of sheet rubber over the end of the stop-cock, and open it.

EXERCISE 194. In the laboratory will be furnished you a piece of apparatus called a "weight lifter." It consists of a brass cylinder in which a piston works tightly, and of a brass plate to which is attached a tube leading to the air-pump. Attach 20 or 30 kgs. of weight to the piston. Place the brass plate on top of the cylinder, connect with the air-pump by means of the tube, and exhaust. What do you observe? Explain.

EXERCISE 195. Over the smaller end of a rubber stopper containing one or more perforations, place a piece of rubber, the size of the stopper, fastening it firmly on one side. Place the stopper in the end of a glass tube. Wrap the end of a stick, a little longer than the tube, with a piece of cloth until it fits the tube closely. Place the end of the

tube containing the stopper in a vessel of water. Lower the stick until it comes in contact with the stopper. Now raise it. Repeat several times. What do you observe? Explain the principle and action of the lifting pump.

Prepare another stopper and tubing, as above, and attach it to the stoppered end of the first, by means of a short piece of rubber tubing. Place the stoppered end of the second tube in the vessel and repeat as above.

EXERCISE 196. Place a vessel, nearly filled with water, on the table. Fill a piece of rubber tubing with water and place one end of it in the vessel. Place a vessel on the floor to catch the water as it flows through the tube. Compute the force with which the water flows through the tube at the end of any interval during the flow. What is such a piece of apparatus called? Explain the cause of the flow of water through the tube. Make a diagram illustrating the action of "Intermittent Springs." Explain the principle.

9. QUESTIONS.

1. How high can water be raised by a perfect lifting-pump, when the barometer stands at 760 mm? How high can mercury be raised under the same conditions? Also alcohol?

2. The sectional area of a "weight lifter" being 60 (cm^2), what weight can be raised by it?

3. Over how high a ridge can water be continuously carried in a siphon, the minimum standing of the barometer being 690 cm?

4. What is the greatest pull that may be resisted by Magdeburg hemispheres 16 cm in diameter?

5. If the capacity of the barrel of an air-pump is ¼ that of the receiver, what part of the air will remain in the receiver at the end of the fourth stroke of the piston?

METEOROLOGY.

EXERCISE 198. Read the barometer three times each day during a period of two weeks, and record as in Exercise 7. Read the thermometer immediately after reading the barometer, and record on same page with barometric reading.

WEATHER.

EXERCISE 199. Prepare a weather map from data given.

[NOTE. Readings of the barometer, thermometer, wind, etc., will be furnished from the latest report of the Signal Service. Maps will be purchased at the Chief Signal Office, Washington, D. C.]

EXERCISE 200. Prepare a second map from data given.

EXERCISE 201. Prepare a third map from data given.

EXERCISE 202. Prepare a fourth map from data given.

EXERCISE 203. Read the "Weather Signals."

Read, five days in succession, the order of the flags displayed on the Signal Service Office, and record.

EXERCISE 204. Construct on a page of your record book a copy of one of the weather maps furnished you.

Read—

BUCHAN—Introduction to Meteorology.

SCOTT—Meterology (International Science Series.)

10. QUESTIONS.

1. Define meterology.

2. Describe the principal instruments used in making observations.

3. How does modern meterology differ from its earlier study?

4. Give briefly the history of the origin and growth of the Signal Service.

5. Describe the method by which weather forecasts are made.

SECTION II.

MAGNETISM AND ELECTRICITY.

DIVISION I.

INTRODUCTION.

EXERCISE 205. Suspend, in a paper stirrup, by means of a silk thread, just above the laboratory table, the steel bar furnished you. Bring one end of a second bar near one end of the suspended bar. What do you observe?. Reverse the bar and repeat. What do you observe? Repeat, using the other end of the suspended bar. What are your observations?

EXERCISE 206. Provide yourself with several large needles. Holding one of them by the center, between the thumb and finger, and the center of one of the bars in the other hand, draw the pointed end of the needle firmly across one end of the bar, and then the other end of the needle across the other end of the bar. Repeat fifteen or twenty times. Prepare a second needle in like manner. Now repeat Exercise 205, using the needles instead of the bars. Substitute for the paper stirrup a small piece of cork, passing the needle through it. What is the law of attraction and repulsion? What is the name given to the bars and needles used above? How are the ends designated? Name and describe different kinds of magnets.

See Avery, Arts. 423 and 424; Gage, Arts. 185 and 186.

EXERCISE 207. Break one of the needles used above and use one of the parts as in the previous exercise. What is the effect?

See Avery, Art. 430; Gage, Art. 186.

EXERCISE 208. Wrap a bar magnet in a piece of paper or cloth and repeat some of the previous exercises. What is the effect? Is the attraction and repulsion affected by holding a sheet of zinc, brass or glass between the magnets?

See Avery, Art. 432; Gage, Art. 187.

EXERCISE 209. Place a piece of glass upon a bar magnet resting on the table. Sprinkle fine iron filings on the glass, gently tapping it. Repeat several times. What do you observe?. Repeat, using a piece of paper.

See Avery, Art. 433.

EXERCISE 210. Prepare several small needles, as in Exercise 206, press them through thin pieces of cork and float on a dish of water. Slowly bring first one end of a magnet and then the other, near them. What is the effect? Explain.

EXERCISE 211. Dip first one end of the magnet and then the other into iron filings. Show the same effect by using tacks. Why do you get different manifestations from those in Exercise 210?

EXERCISE 212. Poise the center of a ruler upon a smooth support. Bring a magnet near one end. Are you able to make the ruler rotate? Can you both repel and attract it? Explain.

EXERCISE 213. Place a long bar magnet on the table and bring the needles, suspended in a previous exercise, directly over the center of it. Slowly move, first toward

one end then toward the other. What do you observe? Explain.

EXERCISE 214. Place a strong bar magnet on a wooden support resting on the table, so that one end of the bar projects over the support. Bring a tack in contact with the projecting end and release. Now bring another tack in contact with the first, and so on as long as they will continue in contact when released. Now, slowly slide a second magnet along the first, with poles reversed. What effect does it have upon the tacks? Explain.

EXERCISE 215. In the laboratory will be furnished you a wooden sphere, mounted so that it may be rotated on one of its axes. Through its equatorial diameter is passed a bar magnet. Over the equator of this sphere is suspended a magnetic needle. Place the sphere so that the needle shall be in the plane of the earth's meridian. Rotate the sphere. What do you observe?

NOTE. Imagining this sphere to be the earth, you have illustrated the variations of the magnetic needles in the different latitudes.

EXERCISE 216. Magnetize a circular steel disk, thus forming poles at the extremities of one of its diameters. Place it beneath a plate of glass. Sift iron filings over the glass. Gently tap the glass. What do you observe? If you imagine a large number of plates magnetized and intersecting so that their polar diameters coincide, do you think the sphere thus formed would act magnetically, as did the sphere in the previous exercise, or differently? Why?

EXERCISE 217. Make diagrams of several different forms of steel magnets. What is an armature? What is meant

by the "variations of the magnetic needle?" How does the north magnetic pole differ in position from its corresponding geographical pole?

See Avery, Arts. 437 and 438; Gage, Arts. 191 to 198.

DIVISION II.

FRICTIONAL ELECTRICITY.

EXERCISE 218. In the laboratory will be furnished you an ebonite, a resinous (sealing wax), and a glass rod; also a piece of flannel and a piece of silk. Place a few small pieces of paper on the table before you. Rub the ebonite rod with the flannel and bring it near the pieces of paper. What do you observe? Repeat, using the other end of the rod. Are your observations the same? Repeat, using small pieces of silk thread. Repeat, using the sealing wax with the pieces of paper, and then the thread. Repeat, using the glass rod with the pieces of paper and silk. Now place a watch crystal on the table with the convex side up. Place another crystal on this with the convex side down. Electrify (rub with the silk) the sealing wax, and balance it on the watch crystal. Electrify the ebonite and bring it near to the sealing wax. What is the effect? Electrify the glass rod and bring it near the sealing wax. What do you observe? Again electrify the sealing wax and balance on the watch crystals. Electrify a second piece of sealing wax and bring it near the first. What is the effect? Substituting a paper or wire stirrup, suspended by a silk thread, for the watch crystals, repeat as above, using glass rods instead of sealing

wax. Repeat, using ebonite instead of glass. Tabulate all the results obtained in the exercise.

EXERCISE 219. Attach a pith-ball to a piece of silk thread and suspend over the table. At some distance from this suspend a pith-ball by means of a linen thread. Using either the glass rod or the sealing wax, electrify and bring near to the first pith-ball. What is the effect? Electrify again, and now allow the ball to touch the rod. What do you observe? Now press all parts of the ball against the hand and repeat. Are your observations the same as before? Repeat, using the ball suspended by the linen thread. What are your observations? Explain the varies conditions and changes in the balls and give the causes.

See Avery, Arts. 332–338; Gage, Arts. 210-211.

EXERCISE 220. Support a plate of glass about two inches above the table. Place under it several small pith-balls. Rub the glass with a piece of silk. What are your observations? Explain.

EXERCISE 221. In the laboratory will be furnished you a bottle, through the cork stopper of which passes a large copper wire reaching half way to the bottom. The lower end of the wire is bent at right angles, over which rests a piece of tin-foil or gold-leaf. The upper end of the wire is bent so as to form a ring. Repeat Exercise 219, using the wire ring in place of the pith-balls, and making your observations on the tin-foil or gold-leaf. What are they?

EXERCISE 222. Successively connect the copper ring and the glass rod or sealing wax or ebonite by pieces (several feet long) of the following substances: Copper, steel and iron wire; carbon (pieces fastened together with

copper wire); cotton, linen or woolen thread, first thoroughly wet with water, then with water very slightly acidulated; cotton, linen or woolen thread, thoroughly dry; a strip or roll of paper; silk (thoroughly dry); a cotton thread, thoroughly saturated in oil or paraffine; a piece of ebonite, glass, or sealing wax. Repeat as in previous exercise.

See Avery, Art. 324.

CONDUCTORS AND NON-CONDUCTORS.

(FROM WORTHINGTON.)

Silver, Copper, Other metals, Charcoal, Water, pure,	Good Conductors.
The body, Cotton, Dry wood, Marble, Paper,	Partial Conductors.
Oils, Porcelain, Wood, Silk, Resin, Gutta Percha, Shellac, Ebonite, Parafine, Glass, Dry Air,	Non-Conductors or Insulators.

Exercise 223. Provide yourself with two egg-shells, the contents having been removed by blowing through a small opening in the shell. Cover the shells smoothly with tin-foil. Attach a silk thread to each so that you may suspend in a horizontal position. Suspend one of them as you did a pith-ball in the previous exercise. Electrify the glass rod and bring near the egg-shell. Now bring the electroscope (see Exercise 222) near to the other end of the egg-shell. What do you observe. Remove the rod. What do you observe? Now, electrify the rod again and bring near to the egg-shell, as before. While the rod is in this position, touch the other end of the egg-shell with your finger. Now remove the rod and bring the electroscope near to the egg-shell. Are your observations the same as before? Explain. Discharge the egg-shell and the electroscope by touching with the hand. Repeat as above, using the sealing wax instead of the glass rod. What are your observations? Has the egg-shell the same kind of "electricity potential" when the glass rod is used as when the sealing wax? How do you determine whether the electrical potentials are alike or different?

See Avery, Art. 322.

Exercise 224. Suspend two egg-shells so that the ends just touch. Electrify the glass rod and bring near one of the shells. While in this position, remove the other shell by taking hold of the thread some distance above its attachment to the shell. Test the electrical condition of each of the shells. Explain.

Exercise 225. In the laboratory will be furnished you a circular piece of tin plate, to which is attached a glass handle.

There will also be furnished you a circular piece of vulcanite, or rubber, a little larger than the tin plate. Slightly warm the vulcanite and electrify it with flannel or cat-skin. Now place the tin plate on the vulcanite. Remove it and try the effect on a pith ball suspended by silk. Observe the effect. Again place it on the vulcanite, after it has been thoroughly rubbed with the flannel. While in this position touch the brass button on the edge of the tin plate. Now remove it and test its electrical condition by means of the pith-ball or electroscope. Repeat several times, each time touching the knuckle to the brass button after lifting the tin plate from the vulcanite. What do you observe? Make diagrams showing the electrical conditions of the plates as used above. See Worthington, Physical Laboratory Practice, page 259.

EXERCISE 226. In the laboratory will be furnished you a glass jar, coated with tin-foil over the lower two-thirds of its inner and outer surface. Through the stopper passes a brass rod, the upper end terminating in a brass ball, and to the lower end is attached a metallic chain reaching to the tin-foil coating. Electrify the electroscope, as in the previous exercise, each time bringing the plate in contact with the brass knob while the other hand rests upon the coating of the jar. After repeating several times, bend a wire so that it will reach from the outside coating to the brass knob. Attach the center of this wire to a glass rod. Now, holding it by means of the rod, bring one end of the wire in contact with the outer coating and the other end in contact with the knob. What do you observe? Explain.

See Avery, Arts. 353–359.

EXERCISE 227. (With the assistance of your instructor.) In the laboratory will be furnished you a board about one meter long, at the center of each side of which is a vertical glass post, between which, on an axis, is mounted a circular plate of glass. At one end of the axis is a handle, by means of which the plate may be rotated. At either extremity of the board is a glass post, on the top of which is mounted a brass covered ball. At the base of the ball is a forked piece of metal so mounted as to be on either side of the plate. Silk pads are so placed on this piece as to come in contact with the sides of the plate. The brass ball is connected with the ground by means of a wire or chain. To the post at the other end is attached a second piece of forked metal, placed in a similar manner in regard to the plate. In place of the pads are metallic points projecting in the direction of the plate, and nearly touching it. While the plate is being rotated, stand on a stool with glass legs (or board resting no bottles), holding the knuckle near the ball to which the toothed piece of metal is attached, occasionally touching it. Now, bring your knuckle near to that of a class-mate. What occurs? Explain

EXERCISE 228. Repeat Exercise 227, but instead of standing on a stool, hold in the hand a Leyden jar (see Exercise 226) with the knob near that of the plate-machine (see Exercise 227). After a number of sparks have passed between the knobs, discharge the jar as in Exercise 226. Explain what takes place and how you charge the jar.

See Avery, Art. 354.

EXERCISE 229. (Holtz machine.) In the laboratory will be furnished you a frame-work similar to that described

in the previous exercise. It consists of two thin circular plates of glass, the larger of which is firmly attached to fixed pillars. The smaller may be rotated rapidly near it. There are two holes in the fixed plate near the extremities of its horizontal diameter. To the sides of these openings are fastened paper bands called armatures. Opposite these armatures, and separated from them by the revolving plate, are two metallic combs, connected respectively with the two holes at the sides of the plates. One of these knobs is carried by a sliding rod, so that their distances apart are easily adjusted. In using the machine the knobs are placed in contact, one of the armatures is electrified by holding against it an electrified sheet of vulcanite, the handle is turned for a short time, and the knobs are gradually separated. Observe and record the result. Explain the action of the machine.

See Avery, Art. 349; S. P. Thompson, Electricity and Magnetism, Art. 46.

DIVISION III.

GALVANIC OR VOLTAIC ELECTRICITY.

EXERCISE 230. Fill a small vessel, as a beaker or tumbler, half full of water. Place also in the vessel a strip of zinc and a strip of copper, each about 2 x 10 cm. Do you observe any unusual phenomenon? Now add, slowly (stirring), about one-fifth as much sulphuric acid as you have water. Do you now observe anything new? Remove the strips, dry them, and solder to one end of each a piece of copper wire about 15 cm. long. Moisten

the zinc with acid and rub the surface with mercury. Again place the strips in the vessel (not allowing them to touch), bringing the ends of the wires together. Observe the action that takes place in the liquid. Now ask an assistant to place "in the circuit" for you "a galvanometer" (see Avery, Art. 418 and Appendix L; or Gage, Art. 199). Bring the wires together and note the reading of the galvanometer. Now place "in the circuit," *i. e.* connect the wire by means of the following substances: a roll of paper, a piece of twine, a piece of silk, a piece of glass, a piece of brass wire, a piece of iron wire, a piece of carbon, a piece of graphite (lead pencil), etc., etc. Note the galvanometer in each case. Compare the results with the table of conductors given above.

EXERCISE 231. Magnetize a large sewing needle as described in a previous exercise. Suspend it so that it will hang in a horizontal position. "Close the circuit" in the apparatus used in the previous exercise, by means of a copper wire. Now hold a portion of the wire forming the circuit, first, parallel to and just below the middle, then just above, and then to either side. Record all observations carefully. Now move the vessel to the opposite side of the needle. Repeat as above, recording observations very carefully.

See Avery, Art. 377; Gage, Art. 183.

Repeat Exercise 231, using "Oerstead's Law Apparatus."

Define the following terms:

Cell (or galvanic or voltaic element).

Battery.

Plates—positive and negative.

Battery fluid.
Conductor.
Electrodes or poles.
Magnetic needle or compass.
Energy (electrical).
Making, breaking, opening and closing the circuit.
Direction of the current (Ampres' law for determining).
Potential (electrical).

See Avery, Arts. 375, 376, 377, 378, 384 and 589; Gage, Arts. 151 to 161.

EXERCISE 232. Substituting for the vessel used above, one of the cells furnished you in the laboratory, break the circuit and wind one end of the wire around the end of a file. Draw the other end of the wire rapidly over the surface of the file. What do you observe? Explain.

EXERCISE 233. Wind a piece of paper around a large nail or a small iron rod. Around the paper make about thirty turns of "insulated" wire. Attach the ends of the wire to the electrodes of a cell furnished you. Now use the "electro-magnet," as in the exercise in which you used the steel magnet, tacks and iron filings. What is the effect of removing one of the wires from the electrode, or of breaking the circuit in any way? Repeat, using the various cells furnished you. Name the different kinds of cells.

See Avery, Arts. 391–397; Gage, Arts. 163–167.

EXERCISE 234. By means of the "voltmeter" (see Gage, 173) determine relatively the currents produced by the several forms of cells furnished you. Repeat, using the "tangent galvanometer."

UofM

EXERCISE 235. In the laboratory will be furnished you four coils of wire, designated respectively A, B, C and D. A contains 40 ft. of No. 20 cu. wire, B 20 ft. of the same wire, C 40 ft. of No. 32 cu. wire, and D 20 ft. of the same wire. What is the relation of lengths of conductors to their resistances?—of diameter of wires to resistances?

Resistance depends upon,
- (External.)
  - Material.
  - Length.
  - Cross Section.
- (Internal.)
  - Size of plates.
  - Distance of plates apart.

What is the practical unit of resistance? See Avery, Art. 386; Gage, Art. 178; "For Reference," above.

Give formulas for Resistance, external and internal.

EXERCISE 236. Determine the resistance of several coils of wire by means of the Rheostat furnished you.

See Avery, Appendix M; S. P. Thompson, Arts. 355–362; Trowbridge, page 319; Kemple, Hand Book of Electrical Testing; Chaps. I. and II.

Solve the problems in Gage, page 204.

Define Electro Motive Force = E M F = E.

In what three ways may Current Electricity be produced?

Volt.

Ampere.

Give Ohm's Law.

Give the formula for Ohm's law.

See Gage, Arts. 180–183.

Solve problem in Gage, page 207.

Requirements of a Battery:

See Gage, Art. 184.

Arrangement of Batteries:

See Gage, Art. 183.

Solve problems in Gage, pages 209 and 210.

Shunts:

See Avery, Art. 104.

EXERCISE 237. Join four Leclanche cells in series. Shunt the current by forming one branch by means of coil A and the other by coil B. Place the tangent galvanometer first in the branch formed by A, note the reading, and then place it in B and note the reading. How do the tangents of the angles of deflection compare? (See table of tangents. Now remove coil A and put D in its place. Note the deflection of the needle. Now remove D and put C in its place. Note as above and compare. What are the results of your observations?

Again remove C and in its place put a coil of unknown length and diameter. Compare with B, as above.

What is the law for the strength of currents in the branches of a shunt.

See Avery, Art. 404.

EFFECT OF CURRENT UPON CHEMICAL COMPOUNDS.

EXERCISE 238. (With an assistant.) Connect the poles of the battery used above with the electrodes of the eudiometer (see Gage, p. 195; Shepard's Chemistry, p. 41), which has been filled with water slightly acidulated with sulphuric acid, (1 part of acid to 20 of water.) When the water has fallen about one-half its former height, remove the battery. Charge a Leyden jar by means of the Plate

Machine or Holtz Machine. Place one knob of a discharger on the outer coating of the jar. Now place the knob of the jar in contact with one of the platinum wires at the top of the eudiometer and the free knob of the discharger in contact with the other wire at the top of the eudiometer. What do you observe?

EXERCISE 239. (With an assistant.) Connect the battery used above with the electrodes of Hoffman's apparatus, after having properly filled it with acidulated water. Continue the action of the battery until the liquid is partly removed from the arms. What has occurred? What is the ratio of the volumes of gases formed?

EXERCISE 240. From the positive pole of a voltaic battery suspend a strip of copper, and from the negative pole suspend a silver coin. Place the copper and silver in a strong solution of copper sulphate. Close the current and allow the apparatus to stand for half an hour or more. What change takes place in the silver coin?

See Avery, Arts. 410–414; Gage, page 193.

STORAGE BATTERIES.

EXERCISE 241. Suspend two strips of bright sheet lead, facing each other, in a dilute solution of sulphuric acid. Pass a current through these plates by connecting them with four Leclanche cells. What change do you observe in the plates? Remove the battery and introduce a tangent galvanometer in its place. Does it indicate a current?

Introduce an electric bell in place of the galvanometer.

See Avery, Art. 415.

EXERCISE 242. In a beaker or similar vessel place a solution of stennous chloride ($Sn\ Cl_2$). Place the platinum

electrodes of the Leclanche battery in the solution as far apart as possible. Note carefully for ten or fifteen minutes. What do you observe?

PREPARATION OF BATTERIES.

EXERCISE 243. Construct a potassium dichromate cell, using the substances and proportions given below:

Formula:—

H_2SO_4	28 (cm^3)
H_2O	85 (cm^3)
$K_2G_2O_7$	20 g.

Thoroughly mix, adding the acid to the water slowly, and stirring. Then add the potassium dichromate and allow the mixture to cool. Place a negative (copper or carbon) and a positive (zinc) plate in the solution and test with the galvanometer.

EXERCISE 244. Construct a gravity cell.

Formula:—

H_2O	50 (cm^3.)
$CuSO_4$	25 g.

Place a copper plate in the bottom of the vessel and suspend a zinc plate in the upper part of the fluid. Test as above.

EXERCISE 245. Construct a Leclanche cell.

Formula:—

NH_4Cl	50 g.
H_2O	125 c. c.

Plates, zinc and carbon. Test as above.

DIVISION IV.

INDUCED ELECTRICITY,

OR

Currents Produced by Other Currents or Magnets.

EXERCISE 246. In the laboratory will be furnished you a coil of about 40 turns of large insulated copper wire (about No. 16). Attach the ends of this coil to the binding posts of the tangent galvanometer. Place the coil in a vertical position. A similar coil (but smaller) will be furnished you. Attach the ends to the Leclanche battery. Watch the galvanometer carefully during the following exercise: Pass one end of the second coil into the first. Remove it. Repeat several times. Reverse the ends of the second coil and repeat several times. Now place the second coil inside the first and open the circuit. Now close it. Change ends and repeat. In the above substitute a bar magnet for the second coil. Compare with the above.

EXERCISE 247. In the laboratory will be furnished you a coil of several hundred turns of fine (No. 32) copper wire. Also you will find a smaller coil of large (No. 20), i. e. 60 or 80 turns. Repeat as in the exercise above.

Also place a piece of soft iron within the large coil. Approach the end of the iron with a strong magnet. Observe as above. Tabulate the results of your observations.

See Avery, Arts. 456–463; Gage, Art. 199; Gage, Introduction to Physical Science, 177–178.

EXERCISE 248. (*a*) (Ruhmkorff Coil.) In the labora-

tory will be furnished you a block on which is mounted a large coil of small wire, the ends of which terminate in the binding posts on the upper side of the spool. Through the binding posts are passed metallic rods, the distance between the ends of which may be adjusted at pleasure. Within this coil is a second coil of large wire, the center of which is filled with a bundle of soft iron rods or wires. One end of the second coil is attached to a binding post, supporting a straight steel spring on which is a piece of soft iron, so placed that it is but a short distance from the end of the bundle of wires. A second binding post is placed in front of the soft piece of iron. Connect the binding posts with the poles of a battery. Gradually separate the rods over the first coil. What are your observations? Explain the action of the apparatus.

See Avery, Art. 459; Gage, Arts. 203 and 204.

(*b*) Examine carefully the construction of the Electric Bell furnished. Place it in the circuit of one Leclanche cell. Watch carefully its action. Explain its construction. What parts are similar to parts in the Ruhmkorff Coil? Make a diagram in your record book.

EXERCISE 249. In the laboratory will be furnished you a box in one side of which is a large compound magnet. Over the poles of the magnet an helix is rotated rapidly by means of a handle at the side of the box. The ends of the wire are connected with pieces of metal on opposite ends of the axis on which the helix rotates. A steel strip rests on the axis and is connected with one terminal on the outside of the box. The end of the axis is connected with another terminal on the opposite side of the box. Remove the armature and place a finger of each hand on a terminal while

the helix is being rotated. What is the effect? Explain the construction of the machine.

See Gage, Art. 200.

DYNAMO-ELECTIC MACHINERY.

See Avery, Arts. 464–467; Gage, Arts 200–201; S. P. Thompson's Dynamo-Electric Machinery, pp. 36, 37, 38, 47, 50, 76 and 79.

NOTE. At this stage of your work your instructor will spend several days with you, at the various electric light and power plants in the city, studying with you the different forms of dynamos, motors, and the various apparatus used in connection with the systems of electric lighting. After studying these forms carefully make diagrams in your record book of the following: The magneto-machine; the Gramme ring, Siemen, Edison, Brush and Thomson and Houston armatures; the simplest form of commutator; the Brush and the Thomson and Houston commutators; the forms and positions of the field magnets in the Brush and in the Thomson and Houston machines; a longitudinal and a transverse section of the Brush and of the Thompson and Houston machines when in position; an arc and an incandescent lamp; the method of connecting the arc and the incandescent lamps with the line wires; and the "three line" system of Edison.

Sufficient time should be given to these diagrams to insure neatness and accuracy.

THERMO ELECTRICITY.

EXERCISE 250. Twist together the ends of pieces of German silver and of iron wire. Attach the other ends to the binding posts of the astatic galvanometer. Heat the twisted

ends of the wire. Is the galvanometer needle deflected? Where does the current originate?

EXERCISE 251. In the laboratory will be furnished you a brass support on which is mounted a case containing an alternating series of bismuth and antimony bars. Join the bismuth bars to one terminal of the astatic galvanometer, and the antimony bars to the other. Remove one of the caps from the case, and in its place put the conical brass cup furnished you. Light a match, and hold it a few inches directly in front of the conical cup. Is the needle of the galvanometer deflected? See Avery, Arts. 419-422.

ATTRACTION AND REPULSION BETWEEN CURRENTS. ALSO BETWEEN MAGNETS AND CURRENTS.

See Gage, Art. 189.

EXERCISE 252. Support a block of wood, in which there are two hooks about a cm. apart, about a metre above one of the laboratory tables. Attach to each of these hooks a straight piece of copper wire of sufficient length to reach nearly to the table. Place the lower end of the wires in a shallow vessel containing mercury. (*a.*) Connect the hooks to one pole of the strong battery furnished you. Connect the other pole of the battery with the mercury, the lower ends of the copper wire having been placed about two cm. apart. What do you observe? Do the currents pass in the same or in opposite directions through the copper wires? (*b.*) Now place the ends of the copper wire together, and connect the hooks respectively to the poles of the battery. What do you observe? Do the currents now pass in the same or in opposite directions? What is the law regarding the action of currents upon each other?

EXERCISE 253. In the laboratory will be furnished you a spiral coil of copper wire, the upper end of which is attached to a brass standard, and the lower end projects into a glass vessel. The bottom of the vessel is connected to one binding post, on which the support of the standard rests, and the standard to the other. Pour mercury into the vessel until it just touches the end of the spiral. Now connect the binding posts with the poles of the strong battery furnished you. What is the effect? Explain.

THE ELECTRIC TELEGRAPH.

See Avery, Arts. 444-448; see Gage, Arts. 240-242.

EXERCISE 254. Place the "key" and "sounder," furnished you, in a current of a Laclanche cell. Alternately close and open the circuit by pressing on the key. What is the effect upon the sounder? Examine the key and sounder carefully, and explain their construction by making neat and accurate diagrams. See Prescott, The "Speaking Telephone, Phonograph, etc," Ch. II.

Write in your record books a list of the applications of electricity to the arts and industries.

SECTION III.

SOUND.

EXERCISE 255. Make a spiral spring by winding a piece of brass or steel wire around a lead pencil. Suspend one end above the laboratory table and attach a weight to the other end. Press two of the turns of wire apart, as with a wedge, and remove quickly. How does it affect the weight? Make a mark on one of the turns near the lower end of the

coil. Apply a wedge as before, and note the movement. Make several spirals of different sizes and attach different weights to each. Note the movement of the different parts as above. How does the density of the different parts of the spiral vary in the different cases? Note the varying densities of a given portion of a spiral while vibrating. Note the intervals of time during the changing of the density.

EXERCISE 256. Place a candle or a small flame from the Bunsen burner near the constricted end of a long tube resting on the table. Strike two books or pieces of board together in front of the other end of the tube. How does it affect the flame? Can you imagine air in the tube moving similarly to the spirals of wire?

EXERCISE 257. Firmly attach one end of a flexible stick to the table. Press the other end to one side as far as you can, without breaking, and release. What do you hear and observe? Repeat, using other flexible materials.

EXERCISE 258. Place your ear at one end of the laboratory table and ask some one to scratch the under side of the other end with a pin or a piece of wire. Can you hear it? Can you hear it when your ear is not in contact with the table?

EXERCISE 259. Remove the bottoms from two tin cans and firmly tie a piece of membrane across one end of each. Make a small hole in the center of each membrane. Place the cans in a horizontal position, 25 or 30 m. apart, having connected the membranes by a string passing through the holes in them and attached to a small piece of metal. Secure the cans so that the string shall be tense.

Place the ear at the opening, while some one speaks into the opening of the other can. What is the effect? What is the name of the piece of apparatus thus constructed? Tie a piece of ribbon or colored card at some point on the string connecting the membranes. Watch it while some one is speaking into one of the cans. What is the effect?

See Gage, Art. 292.

EXERCISE 260. In the laboratory will be furnished you a heavy gong mounted upon an iron support. Place this upon the table. Suspend a pith-ball so that it will rest lightly against it. Draw a resined bow across the edge of the gong. Explain the cause of the sound produced.

EXERCISE 261. In the laboratory will be furnished you a forked piece of steel. Remove it from the box on which it is mounted. Tap one of the prongs and hold it near the ear. Tap again and rest the base on the table. Tap again and rest the base upon the box from which it was removed. Explain the cause of the different results obtained.

EXERCISE 262. A thick glass plate and large double clamp will be furnished you. Securely attach the clamp to the corner of the laboratory table and firmly secure the plate in the clamp. Sprinkle fine sand on the plate. Place the finger at the center of one edge and draw a resined bow several times across the center of the adjoining edge. How does it affect the sound? Place the thumb and finger on the edge of the plate at equal distances from the corners, and draw the bow as before. How do the lines formed by the sand vary in shape? Obtain as many forms as possible by changing the positions of the thumb and finger and the point at which you draw the bow.

Who first performed this exercise?

See Gage, Art. 296.

EXERCISE 263. In the laboratory will be furnished you a glass jar in which is suspended a bell. The jar is closed by an air-tight stopper, in which is fitted a stopcock. Ring the bell by shaking the jar. Can you hear it distinctly? Now exhaust the jar at the air pump, and close the stopcock. Remove the jar and ring the bell by shaking it. What is the difference in sound? What is the cause of the change? Explain.

EXERCISE 264. In the laboratory will be furnished you "conjugate reflectors." Place them in position at opposite ends of the laboratory tables. Suspend a watch at the "focus" of one of the reflectors, and place an ear trumpet to your ear and at the other focus. Is sound reflected?

Explain the cause of echo?

EXERCISE 265. A piece of rubber hose about 20 m. long will be furnished you. Insert a large funnel into either end. Stretch the hose in the lower hall of the "main building," and ask a classmate to speak in a low tone into one funnel while you hold your ear near the other. What are the results? Explain.

Explain the principle on which ear trumpets are constructed.

See Avery, Arts. 477-504. Learn the italicised parts of the text. Read Deschanel, Chapt. VIII.

EXERCISE 266. In the laboratory will be furnished you a receiver of a Bell telephone. Remove the "cap" and diaphragm, and carefully examine all the parts. See Gage, Art. 245.

EXERCISE 267. Make a diagram explaining the construction of the phonograph. See Gage, Art. 291.

EXERCISE 268. Clamp firmly across one of the ends of the laboratory table a triangular strip of wood. At the distance of a metre from the strip, securely fasten the ends of the guitar strings furnished you. Pass the strings over the strip of wood, and attach light weights to each. The weight should be heavy enough to make the strings tense. Test the pitch of the strings with a violin bow. How do they compare? Place a "bridge" under the centre of one of the strings, and compare the pitch of the two.

Place four times the weight on the longer string. Remove the bridge and compare the pitch.

Replace one of the strings by the heavier one furnished you, and attach equal weights. Compare the pitch.

EXERCISE 269. Repeat the exercise given above with the apparatus (sonometer) furnished you. See Avery, Art. 519; Gage, Art. 282.

EXERCISE 270. Construct a diagram showing the method by which the musical scale is written; also tabulate the following: Relative Names, Absolute Names, Syllables, Relative number of Vibrations. See Avery, Arts. 520-529; Gage, Arts. 279-282. Read Dechanel, Arts. 654-661.

EXERCISE 271. With the assistance of your instructor, produce the "singing flame." Explain the cause of the sound. See Dechanel, p. 789; Gage, p. 292.

EXERCISE 272. A number of glass jars of varying depths and diameters will be furnished you. Place them on the table and slowly fill each with water, at the same time holding a "tuning fork" at the mouth of the jar. Note the dif-

ference in the pitch and the sounds produced as the depth of the water increases. Explain. See Avery, Art. 512; Gage, Art. 272.

EXERCISE 273. In the laboratory will be furnished you an open organ pipe. Produce its "fundamental" by blowing gently in the rubber tube attached; then produce its "overtone" by blowing with greater force.

Repeat, closing the pipe with your hand, or better, with a book or piece of board. What are the "absolute names" of the notes produced? What are the relative and what are the absolute number of vibrations produced? What is the "wave length" of the fundamental of the open pipe in terms of the length of the pipe? Of the overtone? How is it with the closed pipe? See Avery, Arts. 530-534; Gage, pp. 319-320; Dechanel, Arts. 664-665.

Read Tyndall on sound.

EXERCISE 274. Mount the pipe used in the last exercise in a vertical position. Lower into the pipe the "drum head" furnished you, on which sand has been sprinkled. Determine the node of its fundamental by looking through the glass face and observing the point at which the sand is least disturbed when the fundamental is sounded.

EXERCISE 275. In the laboratory will be furnished you a "reed pipe" with an adjustable "tongue." Adjust the tongue so that you are able to produce successively the notes obtained from the pipe used in the previous Exercise. See Avery, Art. 535.

Read carefully the whole subject of sound as treated in Avery, Chapt. VII, learning the definitions; or as given in Gage, Chapt. V.

Read Dechanel chapters on Accoustics, and Tyndall on Sound.

SECTION IV.

RADIANT ENERGY.

DIVISION I.

HEAT.

EXERCISE 275. In the laboratory will be furnished you a piece of apparatus called a "radiometer." Hold it in a vertical position a short distance from a hot stove or radiator. What do you observe? Now hold it so that the rays from the sun fall upon it. What do you observe?

See Gage, Art. 300.

EXERCISE 276. In the laboratory will be furnished you a "Leslie's Cube," an athermous screen, a mirror and the apparatus used in Exercise 251. Fill the Leslie's cube with boiling water and support it above the table in such a manner that a straight line drawn from one of its faces through the opening in the screen will intercept the mirror placed in a horizontal position upon the table. Place the conical cup of the "thermopile" (see Exercise 251) in a corresponding position on the opposite side of the mirror. Is the needle of the galvanometer deflected? Is radiant heat reflected? What is the law?

See Avery, Art. 619.

EXERCISE 277. In the laboratory will be furnished you two large concave reflectors. Place them on the table some distance apart and with concave sides facing each other.

Place Leslie's cube, filled with boiling water, in the focus of one, and the cup of the thermopile at the other focus, facing the reflector. Is the needle of the galvanometer deflected? Is heat reflected?

EXERCISE 278. By means of the large, highly polished concave reflector furnished you, bring the rays of the sun to a focus upon a small ball of cotton. What is the effect? Is heat reflected?

EXERCISE 229. Repeat, using a convex lens instead of the concave reflector. What is the effect? Is heat refracted?

Read Langley's "The New Astronomy," Chap. IV; Avery, Arts. 746–751; Deochanel, Chap. XXIX.

Review Heat as treated under Molecular Motion.

Read Avery, Arts. 626–643.

NOTE. At this stage of your work, your instructor will examine with you several steam engines, and explain the use of the different parts.

EXERCISE 280. Make diagrams illustrating the essential parts of a steam engine.

DIVISION II.

LIGHT.

EXERCISE 281. Darken a room, on one side of which is a window, and on the opposite side a smooth, light surface. Admit the light by making a small opening in the covering of the window. [A window should be selected before which, and some disiance from which, is an object with sharp outlines, as a tree or building.] What do you observe upon the surface opposite the window?

EXERCISE 282. With the laboratory darkened, arrange several cardboard screens through which small openings have been made, so that, when placed on the table, the openings will be in a straight line. Place a luminous flame before the opening of one of the outside screens, and the eye before the other outside screen. Are you able to see the light of the flame? Displace first one screen and then another. Does it prevent the view of the flame?

NOTE.—Calcium, electric or sun light, will be furnished you for the following exercises, when necessary.

EXERCISE 283. In the darkened laboratory on one of the tables, place a cardboard screen in which is an opening over which a piece of tin-foil has been pasted. Place a lamp or gas jet on one side, about 3 dm. distant, and a cardboard screen about the same distance on the other side. Make a pin-hole through the tin-foil. What do you observe on the screen beyond the tin-foil? Increase the number of pin-holes until you have completely removed the tin-foil, leaving one large opening. How has the appearance of the other screen changed?

Explain the cause of images, and on what the distinctness of the image depends. See Avery, Arts. 644-650; Gage, Arts. 301-309; Deschanel, 681-683.

EXERCISE 284. (*a*) In the apparatus used above, substitute for the screen with an opening, another screen in which a circular opening 5 cm. in diameter has been cut. Make the flame or source of light as small and bright as possible. Adjust the screen with opening so that it will be midway between the light and the first screen. What is the ratio of the area of the opening and the illuminated part of

the screen? Repeat several times, readjusting the apparatus, and take as your final result an average of the several trials.

(*b*) Repeat, using instead of the screen with the opening, the circle cut from it, finding the ratio of the area of this circle and the shadow cast. How much larger is the surface illuminated in (*a*) than in (*b*)? What are the relative intensities of illumination per unit of area in (*a*) and (*b*)? Give the law.

See Avery, Art. 654; Gage, Art. 311.

EXERCISE 285. Suspend a ball at the side of and a little below a bright light and make an outline of the shadow cast. Cause the ball to swing slightly. How does the shape of the shadow change? Why is the shadow not circular in form?

EXERCISE 286. Admit the light into a darkened room through a small square opening, so that the beam of light will fall upon the floor or table. Why are the corners of the light figure indistinct in form?

Note the shape of the patches of light seen on the ground in a grove or forest. Explain.

EXERCISE 287. Before a white screen, placed in a vertical position, place a lead pencil or similar object. At some distance beyond the pencil place two flames of unequal intensities. Adjust the flames so that the shadows of the pencil cast upon the screen shall be of equal intensities. What is the ratio of the distance of the flames from the screen? Repeat, readjusting the apparatus. What is the relative intensity of the illumination of the flames? What is the name of the apparatus used?

See Gage, Art. 311; Deschanel, Arts. 691 and 692.

Exercise 288. Place a drop of oil on the center of a circular piece of writing paper and support the paper in a vertical position between the flames used in the previous exercise. Adjust the paper and the lights so that the oiled spot will appear equally illuminated on the two sides. Measure the distance of the flames from the paper. What is the inverse ratio of the squares of the distances? What is the relative intensity of the illuminating powers of the flames?

See Gage, Art. 311.

Exercise 289. In the laboratory will be furnished you a semi-circular piece of board about the circumference of which, and projecting above it, is a strip of tin. At the center and at intervals of ten degrees from it, are small openings. Opposite the central opening is a narrow strip of mirror. Place a bright object before one of the holes and look at the mirror through the corresponding hole on the other side. Are you able to see the object? What is the law of reflection?

See Avery, Arts. 655 and 656; Gage, Art. 315; Deschanel, Arts. 694 and 695.

Exercise 290. Place upon the table, about a meter apart, two screens in vertical positions. Lay a mirror midway between them. Close to the outside of one of the mirrors place a lamp or gas flame. Make a small opening in each screen, a few cm. below the flame. Look at the mirror through the opening in the screen on the opposite side from the lamp. Are you able to see the light from the flame? What is the law of reflection?

See references above.

Exercise 291. In the laboratory will be furnished you a glass tube 4 dm. long and 3 cm. in diameter, about which is wrapped a thick black cloth. Make a pin-hole in a card and place over one end of the tube so that the hole will be in the centre. Place your eye at the other end of tube and direct to a bright light. What do you observe? Explain.

Exercise 292. In a darkened room cause a beam of light to fall obliquely upon a piece of unglazed paper. What is the result? See Gage, Art. 316.

Exercise 293. Place in a beam of light entering a darkened room, a bottle containing smoke, or water and slacked lime, or milk and water. What is the effect. Explain.

Exercise 294. Place a bright object before a mirror. Compare carefully the apparent positions of the image and the object with reference to the mirror. Change your position, and compare again. Applying what you have learned regarding the reflection of light, endeavor to construct a diagram, explaining the cause of the image and its position. Give a rule that will apply in general to such constructions.

See Avery, Arts. 659-662.

See Gage, Art. 317.

See Deschanel, Arts. 698-699.

See Tait, Light, Art. 98.

Exercise 295. In the laboratory will be furnished you two long mirrors. Support them on the table in a horizontal position, facing each other. Place a candle between them at one end, and your eye at the other end. How many images are you able to see? Explain by diagram. See Deschanel, page 888.

EXERCISE 296. Place the two mirrors used above, on the table, so as to form a right angle. Hold a light between them. How many images are formed? Vary the angle of the mirrors. How does it affect the number of images? See Deschanel, Arts. 701-702.

EXERCISE 297. Place a third mirror on the table between the two used as above. How many images are formed? Explain.

EXERCISE 298. Repeat exercise 288, substituting for the plane a concave mirror. Make constructions as above.

Learn the definitions of the following terms: Concave and convex mirrors; virtual and real images, and principal and conjugate foci. See Avery, Gage and Deschanel.

EXERCISE 299. Determine by experiment the principal focus of the concave mirror furnished you. Illustrate by diagram. See Avery, Art. 664; Gage, Art. 319; Deschanel, page 893.

EXERCISE 300. Determine by experiment the conjugate foci of the mirrors furnished you. Illustrate by diagram. See Avery, Arts. 667-668; Gage, page 344; Deschanel, Arts. 707-709; Tait, Light, Arts. 94-101.

NOTE.—You will be required to discuss the formulas referred to in Deschanel and Tait.

EXERCISE 301. Make a diagram illustrating the method by which real images are formed by concave mirrors. Verify by experiment. Make diagrams, illustrating the size and position of the images as the distances of the objects are varied. See Avery, Arts. 669-672; Deschanel, Art. 710; Tait, Light, Art. 102.

EXERCISE 302. Make diagrams illustrating the method by which virtual images are formed by concave mirrors. Verify by experiment. See Avery, Arts. 673-674; Deschanel, pp. 897-904.

EXERCISE 303. Make diagram illustrating the method by which images are formed by convex mirrors. Verify by experiment. See Avery, Art. 675; see Deschanel, Art. 716.

Review carefully the subject of Light as treated thus far.

EXERCISE 304. Reflect a beam of light obliquely upon the surface of water contained in a glass vessel. Make a diagram illustrating the effect of the water upon the beam of light.

EXERCISE 305. Remove the water from the glass vessel used above and place a small regular object, as a coin, on the bottom. Place your eye at some distance from the vessel and in such a position that you can see just the edge of the coin. Now fill the vessel with water and place your eye in its former position. Are you able to see more of the coin than before? Explain.

EXERCISE 306. Look at a pencil placed back of a strip of thick plate glass, held obliquely to the line of sight. What is the effect? Explain.

EXERCISE 307. Substitute for the glass in the above a "cell" nearly filled with water and carbon disulphide. What do you observe? Explain.

Read Gage, Art. 321, and make a diagram illustrating the principle discussed.

EXERCISE 308. Arrange apparatus as described in Avery, Art. 676, and determine the index of refraction by method given in Avery, Art. 678. Determine also the indices of

refraction of alcohol, spirits of terpentine, carbon bisulphate, crown glass, flint glass and lead chromate.

EXERCISE 309. Detrmine the index of refraction of water with as much precision as possible, using the apparatus that will be furnished you especially constructed for the purpose.

EXERCISE 310. With the apparatus used above, determine the "critical angle" and the "angle of total reflection."

See Avery, Arts. 681 and 682; Gage, Arts. 324 and 325. Read Deschanel, Arts. 720–727.

Learn the "Laws of Refraction," Avery, Art. 679. Those who have had Trigonometry read Tait, Light, Chap. IX.

EXERCISE 311. In the laboratory will be furnished you two glass prisms. Fix your eye upon some object not far distant. Now bring one of the prisms, with one side parallel with the line of sight, between your eye and the object. What is the effect? Now bring the other prism in contact with the first, having its position reversed. What is the effect? Make diagram showing the cause of the results obtained in each case. See Gage, Art. 326; Avery, Arts. 685 and 686; Deschanel, Art. 728–730.

EXERCISE 312. Make diagram illustrating the different forms of lenses. Learn Gage, Art. 327, or Avery, Art 687. Make a diagram illustrating the method by which we may conceive lenses to be "built up" from sections of prisms. Learn the definitions of the following terms: Center of curvature; principal axis; optical center; principal focus, and conjugate foci.

EXERCISE 313. In the laboratory will be furnished you an hemispherical glass vessel, mounted upon a tripod. Fill

the vessel with water and reflect a beam of light perpendicularly upon its surface. Make a diagram illustrating the effect.

EXERCISE 314. Fill a generating flask with water and place it in a strong beam of light. Illustrate the effect by diagram. Introduce the lens furnished you into the beam of light in such a manner that the focus of the lens will fall at the center of the flask. Do all the rays pass through a common point? Study carefully and illustrate by diagram. Repeat, using lenses of different focal lengths.

See Avery, Art. 698; Gage, Art. 333.

EXERCISE 315. Determine the focal lengths of all the lenses furnished you.

EXERCISE 316. In the laboratory will be furnished you a support on which is mounted a graduated bar. On this bar are mounted a series of screens, gas jets, reflectors, adjustable slits and convex and concave lenses. With this apparatus perform the following exercises: (*a*) Project upon one of the screens, by means of each of the convex lenses, an image of one of the mounted gas jets. Make a diagram illustrating. What kind of images are formed? Are you able to do the same with the concave lenses? Explain by means of a diagram. (*b*) Place one of the lenses at one extremity of the bar and a gas jet in front of it. Place your eye back of the lens, looking through it at the jet. Adjust until you see the flame distinctly. Illustrate by a diagram. Repeat, using successively all the lenses furnished you.

See Avery, Arts. 692–697; Gage, Arts. 331–532; Deschanel, Art. 742–747; Tait, Light, Art. 146–156.

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EXERCISE 317. Determine the optical center of a lens. See Deschanel, Art. 737.

EXERCISE 318. By means of the port lumiere, introduce a beam of light into the darkened laboratory. Interrupt the beam by means of the "slit screen" furnished you in Exercise 316. Open the slit about one mm. Let the light passing through the slit fall upon the prism furnished you. The edges of the prism should be parallel to the slit, and the faces parallel to the rays of light. Receive the light passing through the prism upon a screen or the wall. What is the effect of the prism upon the light? Make a diagram illustrating it. Place a second prism, reversed, in contact with the first so as to form a parallelopiped, and receive the light passing through it upon a screen or the wall. What is the effect? Make a diagram, illustrating it. Repeat, using the single prism, and collect the light by means of a convex lens or concave mirror. What is the effect? Make a diagram illustrating it. See Avery, Arts. 699-703; Gage, Arts. 334-337; Deschanel, Arts. 775-777.

EXERCISE 319. Repeat Exercise 318, using instead of sunlight, light from the stereopticon. Compare with the results above.

EXERCISE 320. [With the aid of your instructor.] In the laboratory will be furnished you a spectro-goniometer, three glass prisms, a carbon bisulphide prism, a Rowland "diffraction grating," a Bunsen burner, several platinum wires fused in glass rods, and solutions of sodium, potassium, strontuim and lithium salts. Carefully examine the spectra of each of these salts, first using the prisms and then the diffraction grating. Make diagrams illustrating the

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results. Make diagrams illustrating the "prism" and the "diffraction grating" spectroscope. See Deschanel, Arts. 778-791; Lockyer's Spectrum Analysis; Lockyer's, The Spectroscope; Lockyer's Chemistry of the Sun; Tait, Light, Chapt. XVI.

EXERCISE 321. Rotate upon the whirling table the various colored disks furnished you. What is the effect?

See Avery, Art. 705; Gage, Arts. 345–351; Deschanel, Chap. LXIII.

EXERCISE 322. Make diagrams explaining the cause of the rainbow.

See Avery, Arts. 706–710; Deschanel, Art. 796.

EXERCISE 323. In the laboratory will be furnished you an achromatic lens. Examine carefully and make a diagram explaining the principles on which it is constructed.

See Avery, Arts. 711 and 712.

EXERCISE 324. In the laboratory will be furnished you a photographer's camera. With the assistance of your instructor, adjust it upon some object so as to receive its image upon the adjustable screen. Examine the apparatus carefully and make a diagram illustrating its construction. [Your instructor will assist you to prepare one or more photographs.]

See Avery, Art. 723; Deschanel, Arts. 748 and 749.

EXERCISE 325. Obtain at the market the eye of a sheep or ox and ask your instructor in Physiology to dissect it and demonstrate to you its construction. With the lens that has been removed from the eye, project images, as in exercises under convex lenses. Make a diagram showing the arrangement of the parts of the eye.

See Avery, Arts. 724–728; Gage, Art. 365; Deschanel, Arts. 752–755.

EXERCISE 326. In the laboratory will be furnished you a simple microscope or magnifier. Examine some object with it. Make a diagram showing its action.

EXERCISE 327. In the laboratory will be furnished you a compound microscope. Examine some object with it. Study the instrument until you are able to separate all its parts, explain their use, and readjust them. Make a diagram showing its construction.

See Avery, Art. 729; Gage, Art. 362; Deschanel, Art. 760; Phin, The Microscope.

EXERCISE 328. In the laboratory will be furnished you an opera glass. Take it apart and examine carefully. Make a diagram illustrating the construction of the Galilean telescope and the principle of its construction.

See Avery, Art. 739; Deschanel, 764.

EXERCISE 329. In the laboratory will be furnished you an astronomical telescope. With the aid of your instructor examine all its parts carefully. Make a diagram illustrating the principle of its construction.

See Avery, Art. 731; Gage, Art. 363; Dechanel, Art. 761.

EXERCISE 330. Make a diagram illustrating the construction of the terrestrial telescope.

See Avery, Art. 733; Deschanel, Prt. 763.

EXERCISE 331. Make a diagram illustrating the construction of the Newtonian telescope.

See Deschanel, Art. 765; Nolan, The Telescope.

EXERCISE 332. Make a diagram illustrating the construction of the Herschelian telescope.

See Nolan, The Telescope.

EXERCISE 333. Make a diagram illustrating the construction of the Cassegranian telescope.

See Nolan, The Telescope.

EXERCISE 334. Make a diagram illustrating the construction of the Gregorian telescope.

See Nolan, The Telescope.

EXERCISE 335. Examine carefully, with the aid of your instructor, the lenses of the stereopticon. Make a diagram illustrating its construction.

See Avery, Art. 734; Gage, Art. 367; Deschanel, Art. 751.

EXERCISE 336. In the laboratory will be furnished you a stereoscope. Examine it carefully and make a diagram explaining its construction.

See Avery, Arts. 735 and 736; Deschanel, Art. 756.

EXERCISE 337. In the laboratory will be furnished you a piece of apparatus named the "tourmaline tongs." Place one of the pieces of the tourmaline over some small bright object on the table. Now place the second piece of tourmaline upon the first. Slowly rotate the upper piece of tourmaline in its frame, while you are looking through it at the object. What is the effect? Explain.

See Avery, Arts. 737–740; Gage, Art. 353; Deschanel, Art. 827.

EXERCISE 338. In the laboratory will be furnished you a piece of apparatus called "Malus" polariscope. Set each of the reflectors at an angle of 32° to the vertical and reflect

a strong beam of common light upon the lower reflector in such a direction that it will be reflected vertically upwards. Look into the upper reflector in such a manner as to receive the reflected beam. Now rotate the upper reflector upon its horizontal axis. What do you observe?

See Avery, Art. 742; Deschanel, Art. 830.

EXERCISE 339. In the laboratory will be furnished you a piece of Iceland spar. Place it upon a page of one of your books and look at the text through it. What is the effect? Lay a piece of white paper or a card, on which you have made a point with your pencil, against the spar, and look at the point through it. Rotate the spar and card upon an axis parallel to the line of sight. What do you observe?

See Avery, Art. 743; Gage, Art. 354; Deschanel, Arts. 732 and 733.

EXERCISE 340. In the laboratory will be furnished you a piece of apparatus named the "Nicol's prism polariscope." Place the instrument, covered with a black cloth, on a table so that it will face a window. Place a thin film of mica on the stage of the instrument. While rotating it, look through the eye-piece. What do you observe?

See Avery, Arts. 744 and 745; Gage, Art. 355; Deschanel, Art. 832.

Read Deschanel, Arts. 809–814 and 819–821.

Read the appendix to Tait's Light.

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